The Effects and Fate of Chemically Dispersed Crude Oil in a Marine Ecosystem Enclosure — Data Report and Methods

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Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n° 1 en janvier 1982.

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by

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ABSTRACT

Whitney, F.A. ed., MEEE Group. 1984. The effects and fate of chemically dispersed crude oil in a Marine Ecosystem Enclosure - data report and methods. Can. Data Rep. Hydrogr. Ocean Sci.: 29: 77 pp.

This report summarizes the experimental data collected in a study of the chemical fate and biological effects of Prudhoe Bay crude oil dispersed with Corexit 9527 in plastic enclosures. On July 17, 1983, three plastic enclosures of 2.5 m diameter with 16 m depth, were filled with sea water in Patricia Bay in Saanich Inlet, B.C. near the Institute of Ocean Sciences. The experimental conditions in the three enclosures were: (1) control, with a nutrient addition only, (2) nutrients plus chemical dispersant, and (3) nutrients plus chemically dispersed crude oil. Over 25 days, sampling and analyses were carried out to observe the impact of dispersed oil on pelagic marine organims, and to study the removal rate and pathways of crude oil in the enclosed waters.

The study was funded under Phase I of the MEEE Project (Marine Ecosystem Enclosed Experiment) as a cooperative study between Canada (Department of Oceanography at the University of British Columbia and Ocean Chemistry Division of the Institute of Ocean Sciences) and Shandong College of Oceanology), supported by the International Development Research Center, Ottawa.

Keywords: Crude oil, dispersant, effects, fate, data, methods, enclosures.

RÉSUMÉ

Whitney, F.A., ed., MEEE Group. 1984. The effects and fate of chemically dispersed crude oil in a marine ecosystem enclosure - data report and methods. Can. Rep. Hydrogr. Ocean Sci.: 29: 77 pp.

Le présent rapport résume les données expérimentales recueillies dans le cadre d'une étude du devenir chimique et de l'incidence biologique du pétrole brut de la baie Prudhoe, dissous avec du Corexit 9527 dans des réservoirs en plastique. Le 17 juillet 1983, trois réservoirs mesurant 2,5 m de diamètre et 16 m de profondeur ont été remplis d'eau de mer dans la baie Patricia de l'inlet Saanich (C.-B.), près de l'Institut des sciences océaniques. Les conditions expérimentales dans les trois réservoirs étaient les suivantes: (1) témoin: apport d'un bioélément seulement, (2) apport de bioelements et d'un agent de dispersion et (3) apport de bioéléments et de pétrole brut chimiquement dissous. Pendent 25 jours, on a effectué un échantillonnage et des analyses pour observer l'incidence du pétrole dissous sur les organismes marins pelagiques et pour etudier le taux d'élimination et le cheminement du pétrole brut dans les eaux expérimentales.

L'étude fait partie de la première phase du projet MEEE (Expériences en résrvoirs sur l'écosystème marin), financé par le Centre de recherche pour le développement international, à Ottawa. Cette étude est un effort coopératif entre le Canada (Département d'Océanographie de l'Université de la Colombie-Britannique et Division de la chimie océanique de l'Institut des sciences oceaniques) et Shandong (Collège d'Océanologie).

Mots-clés: pétrole brut, agent de dispersion, incidence, devenir, données, méthodes, réservoirs

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We thank Rachel Des Rosiers and the International Development Research Center for supporting Phase 1 of the Marine Ecosystem Enclosed Experiments (MEEE), a Canada/China cooperative project; Julie Poulin and Dee Duncan for typing; Julie Poulin for helping Chinese visitors settle in Sidney; R.W. Macdonald and Sharon Thomson for their comments on the report; many others for their assistance in launching the bags; and the staff at the University of Victoria for assistance with the scanning electron micrographs.

INTRODUCTION

To draw together information from laboratory (small scale) and open water (large scale) studies, various research groups have developed intermediate scale experimental enclosures (see Grice and Reeve, 1982). The size and shape of these enclosures, and their methods of use, depend on the specific interests of each research project. Phytoplankton dynamics are easily accommodated in enclosures containing 3 m^3 of water, whereas larval fish studies require hundreds of tonnes of sea water to provide sufficient zooplankton for fish growth. The system in use extensively at the Institute of Ocean Sciences employs enclosures that isolate 66 m^3 of sea water inside polyethylene bags. The bags are 2.5 m in diameter and are 16 m deep, and are open to the atmosphere. This size container permits a phytoplankton - herbivore-carnivore ecosystem to thrive under natural conditions. A typical study will involve three enclosures, one acting as a control the other two receiving various perturbations.

Oil spills are becoming a greater threat to Canadian shorelines as a result of increasing oil exploration and its marine transport. Where valuable coastal areas are threatened, the use of chemical oil dispersants is viewed as one of the methods of oil clean-up. The dispersant, when applied properly, has the ability to mix oils into sea water, hence diluting them to less hazardous concentrations. In this study, we wished to address questions of the toxicity and fate of chemically dispersed oil in shallow water ecosystems. Three CEEs (Controlled Experiment Ecosystems) were filled with sea water from the upper 20 m in Patricia Bay, near the Institute of Ocean Sciences, on July 17, 1983. The CEEs were treated as follows: #1 was a biological control to which no contaminants were added; #2 had 20 g Corexit 9527 (Exxon) added between 2 and 4 m; #3 had 200 g Prudhoe Bay crude oil (20 mg L^{-1}), 20 g Corexit 9527 (2 mg L^{-1}) and 125 μCi n-(1-^{14}C) hexadecane (0.0125 μCi L^{-1}) added in a layer between 2 and 4 m. Over the following 25 days, plankton counts, biomass measurements and hydrocarbon analyses allowed us to observe the effects and fate of the dispersed cruse oil in a shallow water marine ecosystem.

METHODS

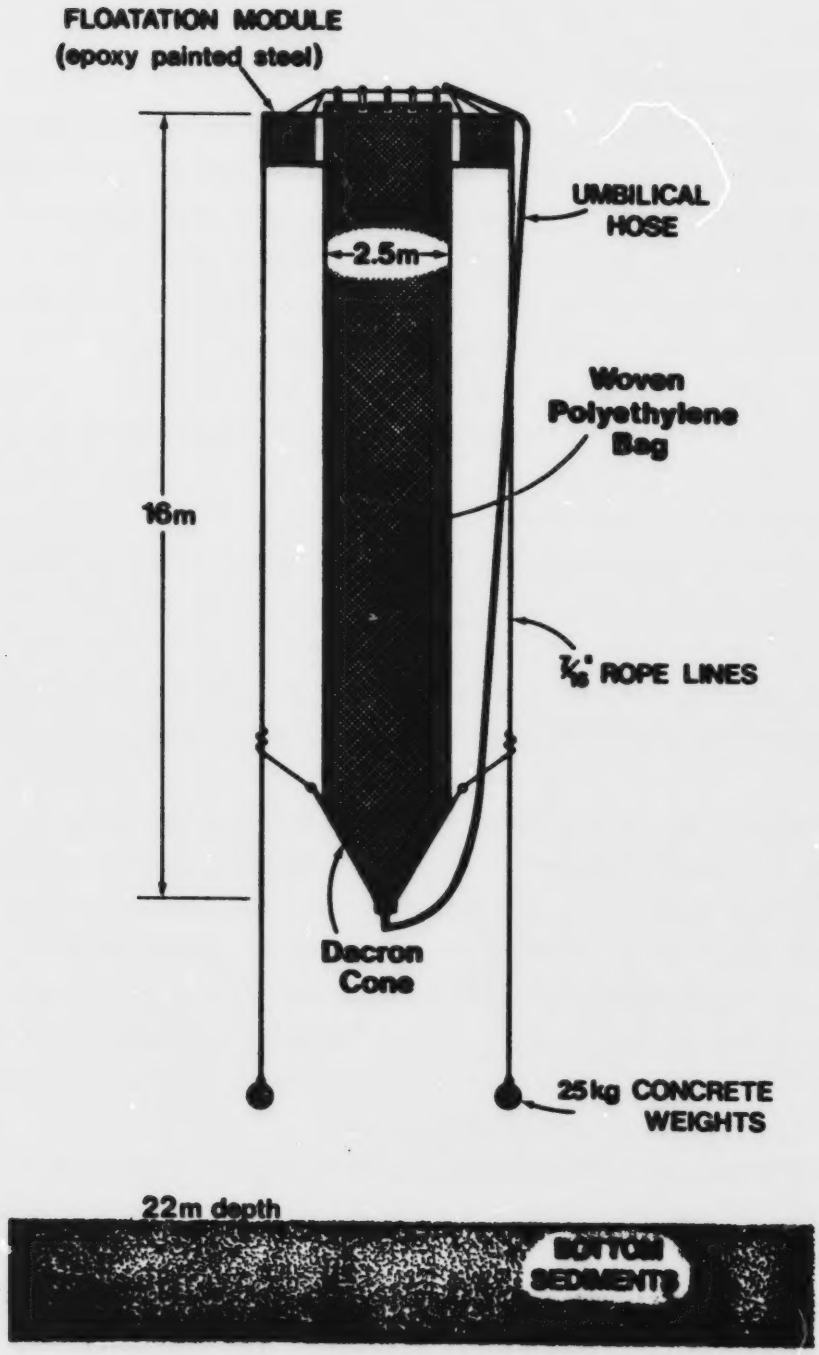
Design of Marine Enclosures

Since 1973, experimental work has been conducted in marine enclosures that were designed and constructed under the Controlled Ecosystem Pollution Experiments (CEPEX) project (Menzel and Case, 1977). When funding ended for CEPEX in 1978, the Ocean Chemistry Division at the Institute of Ocean Sciences, continued using the enclosures, focussing our research on the fate and effects of pollutants in surface marine waters (eg. Iseki et al. 1981; Whitney et al. 1981). A brief description of the enclosure system is given here, but more extensive coverage is given by Menzel and Case (1977), and Grice and Reeve (1982).

Three flotation modules are anchored in Patricia Bay, 1 km from the dock at the Institute of Ocean Sciences. The water depth at this site varies between 20 and 23 m, depending on the tide height. When an experiment is planned using the CEPEX system, polyethylene bags are filled with sea water and are attached to the modules (figure 1). A bag is filled by a team of SCUBA divers who sink the bag to 20 m, hold its mouth horizontal and open, and swim it to the surface. Typically from 70 to 100% of the bag volume (66 m^3) is captured as a stratified water column by this procedure. The balance of the water in this study was surface water added by polyethylene bucket to the enclosures.

The bag dimensions are as follows:

Diameter	2.40 $\pm$ 0.04 m
Length, cylindrical portion	13.6 $\pm$ 0.2 m in water
conical portion	2.0 $\pm$ 0.1 m
overall	16 m, including above water
Opening at bottom	5.0 cm
Umbilical hose	3.2 cm I.D., 20 m long
Volume of enclosure, calculated	66 $\pm$ 2 m^3


FLOATATION MODULE
(epoxy painted steel)
UMBILICAL HOSE
2.5m
Woven Polyethylene Bag
16m
3/16" ROPE LINES
Dacron Cone
25kg CONCRETE WEIGHTS
22m depth
BOTTOM SEDIMENTS

Sampling Procedures

Each sampling day, a field team proceeded by boat to the enclosures. Between 0830 and 1000 h local time, sea water samples and sedimented materials were pumped from bags 1, 2 and 3 using a Little Giant tubing pump (Cole Parmer, Co., Chicago, Ill.) and 30 m of 12.7; mm I.D.(1/8" wall) PVC tubing. By 1015 h, all *in situ* incubations were innoculated and were suspended either inside or outside the bags. Bottles were hung at the mid-point of each sampling interval. Subsequently, oil fluorescence profiles, ^{14}C tracer samples and zooplankton samples were taken, with sampling ending by 1130 h.

Water samples were pumped at a rate of *ca* 6 L min^{-1} from intervals of 0-5 m, 5-10 m and 10-13 m by slowly lowering the PVC tubing through the water column at a constant rate, which varied between 15 and 45 sec m^{-1} depending on the volume of water required. A 10 to 20 L water sample was collected in a polyethylene cubitainer, and this water was subsampled for all measurements except those described immediately below.

Discrete depths were sampled for temperature and salinity by pump, and for ^{14}C tracer measurements by 1.7 L Niskin sampler. Settled material was pumped from the bottom of each bag through the PVC umbilical hose and then through 12.7 mm PVC tubing as it passed through the pump head. An oil fluorescence profile was taken each sampling day in bag 3 by pumping water at *ca* 5 L min^{-1} through 11 mm Teflon tubing and into a Turner fluorometer. While the tubing was being retrieved, samples for total oil were taken from 6 and 3 m.

Following the water sampling, zooplankton tows were made with a 20 cm diameter, 200 µm nylon mesh net, vertically from 13 to 0 m at a rate of *ca* 30 m min^{-1}.

All PVC tubing and cubitainers were rinsed with 10% HCl after each sampling period. Before samples were taken the next day, they were rinsed well with water from their respective bags. (FAW)

Uptake Rates

Primary productivity

125 ml Pyrex glass bottles (1 clear and 1 black) were filled and innoculated with $NaH^{14}CO_3$. *In situ* incubations at 2.5, 7.5 and 11.5 m in each bag lasted 4 h. The procedure is described in Parsons *et al.* (1984).

Relative heterotrophic uptake

^{14}C labelled glucose was added to water samples and incubated as described in Parsons *et al.* (1984).

Heterotrophic bacterioplankton production

The rates of heterotrophic production were quantified by the method described in Fuhrman and Azam (1982). In this study, triplcate subsamples of 20 mL each were incubated in glass tubes *in situ*, with 5.0 nM of high specific activity (50-80 Ci/mmol) thymidine (methyl-^3H). Following 20 minutes of incubation, the samples were immersed in an ice bath prior to cold trichloroacetic acid extraction of soluble cellular pools. Adsorption blanks, poisoned with 0.2 mL formalin per 100 mL sea water prior to isotope addition, were treated identically. The conversion of thymidine incorporation to bacterial numbers was carried out using the factor derived by Fuhrman and Azam (1982).

Nitrate and ammonium uptake

To duplicate 0.5 L water samples, either $^{15}NH_4Cl$ (99 atom %) or $Na^{15}NO_3$ (99 atom %) was added to bring the final tracer addition to 0.1 uM. After 4 h *in situ* incubations, samples were vacuum filtered onto precombusted (500°C, 4 h) Whatman GF/C filters and were frozen in a dessicator. Particulate nitrogen was converted to N_2 gas by the micro-Dumas dry combustion technique (La Roche, 1983) and analyzed for ^{15}N in a Jasco Model N1A-1 emission spectrometer (Fiedler and Proksch, 1975; Cochlan, 1982). Uptake rates are reported as specific uptake, with units of reciprocal time (Dugdale and Goering, 1967) and can be converted to absolute uptake ($\mu M\ time^{-1}$) by multiplying the specific uptake times the particulate nitrogen concentration of the sample. (WPC)

Plankton Counts

Bacterioplankton. Samples collected for bacterial enumeration were immediately fixed with 2 mL filtered (0.2 µm) formalin in 100 mL sea water and were stored at 2 °C in the dark. Fixed samples were vacuum filtered on 0.2 um, 25 mm diameter, Irgalan black stained Nuclepore filters. Direct counts of bacteria numbers were obtained using acridine orange staining, coupled with epi-fluorescence illumination, as described in Hobbie et al. (1977). The volume of the sample filtered (2 to 5 mL) was adjusted to give between 20 and 50 bacteria per field. A minimum of 20 fields were counted for each sample. (KL)

Phytoplankton

Either 10 or 50 mL of Lugol's preserved sample were settled for from 18 to 48 h. Cells were counted in an area equivalent to 89 microscopic fields. Microflagellates were counted at 625 x magnification and all other organisms at 250 x magnification. A minimum of 400 cells were counted per sample (Lund et al. 1958) using an inverted microscope. (TRP)

Zooplankton

Organisms were preserved by adding 4 mL formalin per 100 mL sea water into the samples. A Folsom splitter was used to subsample the zooplankton before counts were made. Routinely, 1/2 to 1/4 of the sample was counted. Plankton counting is discussed in Parsons et al. (1984). (CML)

Chemical Analyses

Carbohydrates Mono and poly-saccharides were analysed by the colorimetric procedures described in Strickland and Parsons (1972) using the modification of Geesey et al. (1978) for analysis of particulates. (WJC)

Chlorophyll a

Analysed by the fluorometric procedure from Strickland and Parsons (1972), using a Turner Designs fluorometer. (PJH)

Dry Weight

Aliquots of sedimented material were taken by pumping the bulk material (19 to 58 L collected each sampling day) through the tubing pump and drawing subsamples into acid cleaned (10% HCl) polyethylene bottle (1 L).

From the 1 L bottle, 10 to 100 mL samples were filtered onto 1.0 µm Nuclepore filters, rinsed with distilled water, dried at 60°C for 24 h and weighed. Filter blanks were rinsed with distilled water, dried and weighed with the samples. (FAW)

Nutrients

Fresh samples were filtered through Whatman GF/C filters and were analysed within 4 h for PO_4 by the method of Murphy and Riley (1962) as automated by Hager et al. (1968), for NO_3 and NO_2 and dissolved Si by the method of Armstrong et al. (1967), and for NH_4 by the method of Koreleff (1970) as automated by Slawyk and MacIsaac (1972). (PJH)

Oil concentrations: fluorescence profiles

A profile was taken as the Teflon tubing (11 mm I.D.) was lowered at 30 sec m^{-1} between 0 and 13 m. Water was pumped through a continuous flow cell on a Turner Model III fluorometer. The fluorometer was outfitted with a 110 811 (7-60) excitation filter, a 110 81b (2A) emission filter, a 10% neutral density filter on the emission side and a 110 855 (T-5 envelope) ultra violet lamp. Each day, the zero reading on the fluorometer was set by pumping surface sea water from outside the bags, through the flow cell. (WJC)

Extraction of oil from filterable particulates

The grade of solvents used in the extraction was "redistilled in glass". Extractions were carried out in batches of 6 including a blank consisting of a filter paper wet with hydrocarbon-free water (distilled from a solution of potassium permanganate (10 g) and potassium hydroxide (4 pellets) distilled-in-glass water (3-4 L)). Each filter paper was rolled up, placed in a threaded culture tube (2 mm x 150 mm) and covered with an ethanolic potassium hydroxide solution (6 ml of 46.7 g/L). A sheet (2 mil) of FEP Teflon much larger than the diameter of the tube was placed over the opening and secured tightly in place to provide a vapour seal. The contents of the tube were heated at 70°C for 1 h in a hot water bath, diluted with an equal volume of hydrocarbon-free distilled water, and heated at 70°C for a further 30 min. The hot liquid was then transferred by pipette into a separatory funnel (125 mL) and the

filter paper and culture tube's interior were rinsed with ethanol (1 mL). The rinsings were transferred to the separatory funnel. The contents of the culture tube were then serially extracted with occasional swirling for 15 min each with dichloromethane/ethanol (8:1, 9 mL) and dichloromethane (8 mL). Each extract in turn was transferred from the culture tube into the separatory funnel and used to extract the latter's contents at room temperature. The extract solutions were combined, washed with hydrocarbon-free distilled water (3 x 4 mL) and dried over anhydrous sodium sulphate. Using a hydrogen-free nitrogen stream, the dried solutions were evaporated to 1 or 2 mL depending on oil content estimated from the colour.

Recovery of oil from oil-spiked filter papers

To each of three pre-weighed glass fibre filter papers (47 mm, Whatman GF/F), an aliquot (15 µL) of Prudhoe Bay crude oil was added and weighed immediately. To each of another two glass fibre filters, an aliquot (15 µL) of Prudhoe Bay crude oil/dichloromethane (1:10 by vol.) was added. To a third filter, a 30 µl aliquot of the same solution was added. An initial weight was recorded after the dichloromethane appeared to have evaporated as judged by a considerable drop in the rate of weight change.

The filter papers were allowed to stand at room temperature in the air for three days. After the standing period, the weight of oil remaining on the filter papers was determined and the loss of weight by evaporation calculated. The residual oil on the filters was then extracted using the procedure described above for filterable particulates from the oiled enclosure and the percentage of oil recovered by the procedure was calculated.

Extraction of oil from polyethylene enclosure material

A subsample (2.5 cm x 102 cm) was cut from each of the three suspended strips of polyethylene enclosure material. Each strip was then extracted in a beaker by immersion and agitation in dichloromethane (90 mL) for 5 min. Three subsamples of material (8 cm x 20 cm) from the sample of the enclosure wall were also extracted as above. A blank

determination using three pieces (15 cm x 20 cm) of unused enclosure wall material was also carried out. Following drying over anhydrous Na_2SO_4 and concentrating where necessary aliquots were transferred to an aluminum foil weighing boat and weighed after evaporation of the solvent.

Extraction of oil in filtrates and slick samples

Filtrates from discrete depth, sediment and vertically integrated samples were extracted with redistilled-in-glass grade dichloromethane to recover oil, although the methods differed somewhat because of differences in the volumes filtered. In the case of discrete depth samples, the filtrate from 400 mL of sea water was serially extracted in a separatory funnel (1 L) with vigorous shaking for a minimum of 5 min using two portions (20 mL and 10 mL) of dichloromethane.

In the case of vertically integrated samples, the filtrate from 3.5 L of sea water was extracted serially in a glass jug using a Red Devil paint shaker (model 5100) with a 7.62 cm (3 in) pulley on the drive shaft. Two portions (140 mL and 70 mL) of dichloromethane were used with 15 min shaking for each extraction. A FEP Teflon sheet provided a seal under the jug's cap. The dichloromethane extracts were pipetted from the jug. After 8 months storage at 4 ^{o}C over 140 mL of dichloromethane, a duplicate set of filtered water samples obtained from the 0-5 m depth interval on July 20, 24, 26, and 29 were also extracted for comparison.

Filtrates from well homogenized samples of sedimented material were extracted according to the procedure described above for the discrete depth samples, although only 100 mL of sample was filtered. Proportions of dichloromethane used and the size of separatory funnel were scaled down accordingly.

The surface slick samples were extracted without filtration using the same proportions of dichloromethane to water as described for the filtrate samples. All the extracts were dried over anhydrous Na_2SO_4 prior to concentration for analysis. In the case of the discrete depth water samples only, the extracts of the filter paper and filtrate from a given sample were combined prior to analysis. For each extract, concentration

to 1 mL was performed by evaporation under a hydrocarbon-free nitrogen stream following , if necessary, rotary evaporation. The duplicate filtrate samples were concentrated to 5 mL and then divided into 2 equal portions; one for eventual $GC^2/MS/DS$ analysis and the other for ^{14}C counting.

Gravimetric analysis of extracts

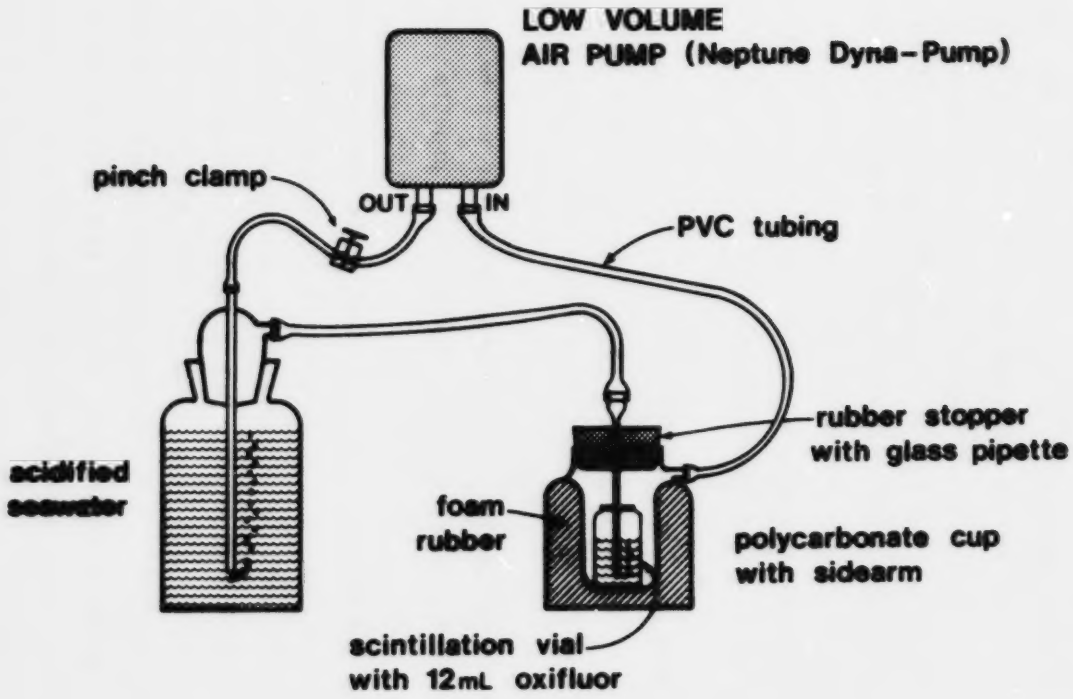
An aliquot (100 µl or less) of a concentrated extract (in dichloromethane or hexane) was allowed to evaporate to dryness at room temperature on a preweighed aluminum foil boat. The residue was weighed using a Mettler M3 balance. The weights of the following extracts were determined: integrated water was filter paper extracts, bag wall extracts, filterable sediment extracts, discrete depth combined extracts, surface slick extracts; and 3 sediment filtrate extracts (July 27, Aug 1 and Aug 4). (WJC)

Particulate organic carbon and nitrogen

2.1 L of sea water and between 10 and 100 mL of sedimented material were filtered onto precombusted 47 mm Whatman GF/C filters (combusted at 500°C for 4 h). Filters were rinsed three times with an aqueous 3% NaCl solution. Samples were stored in aluminum foil and frozen until they were dehydrated in an oven at 60°C for 18 h. Dried samples were held in a dessicator until analyzed. Filter blanks were handled likewise. For analysis, filters were combusted at 750°C in a Perkin-Elmer Model 240 Elemental Analyser. Each day, a minimum of three standards were combusted (Acetanilide, BDH Organic Analytical Standard) to check the performance of the instrument. Gas blanks were run every 3 to 5 samples. Variations in standards from day to day were small enough that all standards were pooled and used in the calculations. (FAW)

^{14}C tracer measurements

a) $^{14}CO_2$ - samples were drawn from 1.7 L Niskin samplers into 500 mL glass stoppered bottles. In the lab, 20 mL of water was withdrawn and the sample was placed in a closed air circulating loop. Concentrated H_2SO_4 (1 mL) was added to the sample then air was bubbled through it to purge the CO_2. A trap with 12 mL of Oxifluor (New England


LOW VOLUME
AIR PUMP (Neptune Dyna-Pump)
pinch clamp
OUT
IN
PVC tubing
rubber stopper
with glass pipette
acidified
seawater
foam
rubber
polycarbonate cup
with sidearm
scintillation vial
with 12mL oxifluor

Nuclear) adsorbed the CO_2 over a 10 min period (see figure). Bubbling rate was set by eye, so that bubbling did not cause the water to "boil" but still created steady mixing in the sample. (WJ & FAW)

b) filter passing extractable ^{14}C - 500 mL of filtrate collected after the water was vacuum filtered through a 47 mm Millipore HA filter (0.45 µm pore size), was extracted by shaking the sample in a 1 L separatory funnel with first 20 mL then with 10 mL dichloromethane, each extraction lasting 5 min. The two extracts were drawn off into a graduated test tube and the dichloromethane was evaporated at room temperature by bubbling N_2 gas through it. The final volume of extract was 3 ± 1 mL, of which 2.0 mL were added to 10 mL Aquasol. (NEN) (WJ, FAW)

c) filter retained ^{14}C - 500 to 600 mL samples were vacuum filtered onto either Millipore HA filters or Nuclepore 3 and 8 µm filters (all filters were 47 mm diameter). The filters were placed in 10 mL Aquasol. (WJC)

d) sediments - while the 1 L sediment subsample was being swirled and mixed by hand, a 1 mL aliquot was withdrawn by pipette and added to 10 mL of Aquasol. (FAW)

e) chemical fractionation of particles - the time and pattern of n-(1-^{14}C)-hexadecane incorporation into biological material was monitored by the cellular fractionation procedure of Li *et al.* (1980), with a modification to enhance the recovery of n-hexadecane (by adding 0.5 mL n-hexadecane to help retain the ^{14}C labelled material during solvent evaporation). Particulates were collected from 400 to 500 mL samples by vacuum filtering onto Whatman GF/C filters which were then frozen with 1.2 mL of distilled water and stored for subsequent analysis. When the filters were thawed, 1.5 mL chloroform and 3.0 mL methanol were added. The suspension was vortex mixed vigorously for 1 min, incubated at $4^{o}C$ for 15 min, filtered through a Whatman GF/C filter, and then washed with 1.5 mL of chloroform. Distilled water (1.2 mL) was added to the filtrate, then it was vortex mixed for 1 min and centrifuged at 700-100 x g for 10 min. Into a scintillation vial was pipetted 2.0 mL of the lower chloroform layer and 0.5 mL n-hexadecane, then the chloroform

was evaporated at room temperature under N_2 gas. To the residue and to a separate 1.0 mL aliquot of the water-methanol layer was added 10 mL Aquasol. The filter was resuspended in 4.0 mL of 5% trichloroacetic acid (w/v in distilled water) and was heated at 95°C for 30 min. The suspension was filtered through another GF/C filter, followed by a 4.0 mL wash with 5% TCA (trichloroacetic acid). A 2.0 mL aliquot of the filtrate was added to a scintillation vial, was dried under N_2 gas and was redissolved in 1.0 mL water. The dried TCA-insoluble material on the filter was also added to a vial, and to both these samples was added 10 mL Aquasol. Four components are obtained in this procedure, chloroform soluble (lipids and free ^{14}C labelled hydrocarbons), methanol/water soluble (low molecular weight metabolites), and hot TCA-insoluble (protein) and hot TCA-soluble (polysaccharide and nucleic acids) compounds. All ^{14}C samples were counted in a Beckman LS 3133 Liquid Scintillation counter, using the external standards-channel ratio method to correct for quenching. (KL)

Other Measurements

Temperature

A precision-grade thermometer (Western Scientific) marked in 0.1°C gradations was held in the outlet of the pumped water until a constant temperature reading was obtained (usually ca 1 min). (FAW)

Salinities

Water samples were drawn into 260 mL glass bottles which had been rinsed three times with sea water. Samples were capped and stored no more than two days before being analysed on a Guildline Model 8400 Autosal salinometer which was standardized daily against I.A.P.S.O. Standard Sea Water (batch 27/7, 1974). (FAW)

Coulter counts

Determined on a Model TA II Coulter Counter following the procedure described in Parsons et al. (1984). (TRP)

Sinking rates

Determined using Bienfang's SETCOL method as described in Parsons et al. (1984). (TRP)

Light profiles

Light extinction was measured at discrete depths using a LI-85 Sensor (Lambda Instruments, Nebraska, U.S.A.). (TRP)

Scanning Electron Microscopy

Estimates of bacterial biomass (as biovolume) were obtained from cell size measurements collected by scanning electron microscopy (SEM). Following sampling, 20 mL sea water were filtered onto 0.2 µm pore size Nuclepore filters at less than 0.1 atm vacuum. Immediately after filtration, the filters were loosely enclosed in aluminum foil and submerged in a solution of 2 mL glutaraldehyde in 100 mL filtered (0.2 µm) sea water which was buffered to pH 7.0 with 0.1 M sodium cacodylate. Following fixation, the samples were desalted and dehydrated by transfers through 75, 50, 25 and 0% filtered sea water and then 10, 25, 50, 75, 90 and 100% ethyl alcohol (distilled water) solutions. The specimens were critical-point dried with liquid CO_2 and were mounted directly on SEM sample stubs with double sided adhesive cellulose tape. In order to reduce charging during subsequent viewing, the perimeter of the sample was grounded to the sample stub by application of conductive silver paint. The samples were coated, under vacuum, with gold and viewed with a Joel JSM-35 scanning electrom microscope at the University of Victoria. (KL)

Direct Observation of Oil Droplets

Phase contrast and epi-fluorescence microscopy were utilized for direct observation of Corexit dispersed oil droplets in the particulate fraction. For epi-fluorescent observation, samples were filtered onto 0.2 µm Nuclepore filters pre-stained with Irgalan Black. Oil droplets fluoresce yellow to red, at an intensity distinctly different from chloroplast autofluorescence, against a black background, under these experimental conditions. This phenomena was observed using a Zeiss Standard microscope fitted with an IV FL epi-fluorescence condensor, a HBO 50 mercury lamp, a BP 450-490 band-pass filter, a FT 510 beam splitter and a LP 520 barrier filter. Photomicrographs were obtained on Kodak Tri-X and Ektachrome films, using a Zeiss camera system.

METHODS' ERRORS

This section attempts to assess the precision, accuracy and limit of detection (LOD) of each of the procedures used in this study. Precision is stated in one of three ways; as s, the standard deviation, as V, the coefficient of variation ($V = \frac{s}{\bar{x}} 100$, where $\bar{x}$ is the mean of replicates), or as CI, the 95% confidence interval (approximately equal to 2s for n> 20). LOD is assessed as three times the standard deviation of the blanks, or it is quoted from reference sources. Accuracy assessments are attempted by comparing recoveries with standard reference materials or by less direct arguments which may show that there is corroborative evidence that supports the validity of the data.

Sampling Methods

Pumped water from depth intervals - each day, the time required for water to travel from the tubing intake to its outlet was measured using rhodamine dye. Tolerance given to these measurements was $\pm$ 2 sec. As tubing was lowered by hand, its descent rate was checked at each meter marking, so that the same amount of water was pumped from each 1 m interval ($\pm$ 2 sec). A typical descent rate of 30 sec m^{-1} through an interval might bias water collection by oversampling one end of an interval by $\pm$ 4 sec and by missampling any 1 m interval by $\pm$ 4 sec (2 sec at each end). Sampling error will depend on the concentration gradients of the parameters being measured and will equal no more than $\pm$ 5% of that gradient. This does not address the problem of patchiness within the enclosures. To obtain a more realistic estimate of reproducibility in sampling, a set of 4 replicates was taken during a MEEE study in 1984. The 5-10 m interval in one CEE was resampled immediately after its usual sampling and chlorophyll *a* and nutrient samples were taken to estimate the replicability obtainable for both particulate and dissolved materials. The four nutrient analyses gave a range of V = $\pm$ 2.4% to 5.4% (n=8, as 4 sets of duplicates for each nutrient). Chlorophyll *a* showed only a slightly higher V = $\pm$ 5.9% (n=8). These analyses are expected to have V of approximately 1 to 5% for nutrients and 5% for chlorophyll *a* according to Strickland and Parsons (1972). Sampling and analysis in this study have a combined error of 2 to 6%. Therefore, sampling error decreases the

precision by about 2%.

Pumped water from discrete depths - the meter markings on the PVC hose were held within 5 cm of the surface for all samples. In the maximum T/S gradients observed in the experiment, this could only account for errors of $\pm$ 0.0025 ^{o}/oo salt and of $\pm$ 0.04 ^{o}C.

Niskin sampling - the hand held line for the 1.7 L Niskin sampler had meter markings that were consistently with 5 cm of the surface when samples were taken. The order in which samples were drawn from the Niskin bottle were always the same (CO_2 first, then water for dissolved and particulate ^{14}C), therefore, sampling precision would equal $\pm$ 5% of the ^{14}C gradient. There is a phenomenon in CEEs that will displace water upward or downward depending on the density of the surrounding water. Steele et al. (1977) observed as much as 1 m horizontal shift in a dye layer in a CEE during the advection of a different density water mass into the bay surrounding the CEEs. This phenomenon happens more dramatically when bags are underfull nearer the end of an experiment.

Fluorometric profiles - this analysis was used as a graphic representation of oil dispersion and mixing in the CEE. The fluorescence scale was not calibrated and the zero level was not rigorously checked. However, the diffusion and advection of salt and fluorescent oils in CEE 3 follow each other very well (see Wong et al. ,1984).

Net tows - the sieving efficiency of the net was not assessed, however, it is expected that for short tows, the filtering efficiency will be near 1. Occasionally, the net was fouled with diatom chains, possibly reducing filtering efficiency.

Analyses

NO_3 & NO_2 - at 10 µM, CI = $\pm$ 0.2 µM; LOD = 0.1 µM. Although not assessed in this study, accuracy of standards is typically $\pm$ 2% of Sagami standards.

NH_4 - at 1.0 µM, CI = $\pm$ 0.07 µM; LOD = 0.05 µM. Although not assessed in this study, standards typically agree with Sagami standards to $\pm$ 5%.

PO_4 - at 1.0 µM, CI = $\pm$ 0.1 µM; LOD = 0.05 µM. Accuracy of

standards is typically ± 1% of Sagami standards.

Dissolved Si - at 10 μM, CI = ± 0.2 μM; LOD = 0.1 μM. Accuracy of standards is typically ± 1% of Sagami standards.

Chlorophyll *a* - at 1.0 mg m^{-3}, CI = ± 0.1 mg m^{-3}; LOD = 0.05 mg m^{-3}. The fluorometer was not calibrated before this experiment, however, a comparison of the chlorophyll:POC ratios from this study and from a later experiment in which the fluorometer had been recently calibrated by the method in Strickland and Parsons (1972) indicated that the chlorophyll values reported in this data compilation are low by about 25%.

Primary productivity - at a carbon fixation rate of 30 mg m^{-3} h^{-1}, where n=2, LOD = 0.05 mg m^{-3} h^{-1}. Accuracy is largely an assessment of what is being measured, a lively topic of debate in current literature.

Note: the above estimates of precision come either from Strickland and Parsons (1972) or Parsons *et al.* (1984).

Bacterial productivity - pooled s = ± 3.9 x 10^{4} cells L^{-1} h^{-1} (n=65). From a single sample of 1.5 x 10 cells l^{-1} h^{-1}, V = ± 6% (n=10). Accuracy is not assessable. During a short period of high growth rates without apparent grazing in CEE 3, bacterial counts and growth rates agreed with each other within ± 5%.

Salinity - replicate conductivity readings were not accepted unless they were within 0.00005 units. The precision of the salinities at this level is ± 0.002 °/oo, usually better. The accuracy of the values is disputable. As Guildline (1981) suggests, the formula of Lewis (1980) is used to convert conductivity to salinity. An earlier formula suggested by Guildline (1975 manual) resulted in salinities that are 0.03 °/oo lower at 29 °/oo than those now obtained. This discrepancy approaches 0 as we approach the conductivity of the I.A.P.S.O. standard sea water.

Temperature - the readability of the thermometer is better than 0.1 °C, however, the main error will arise from warming or cooling of waters in the tubing before reaching the outlet. This error was estimated

as being a maximum of $\pm$ 0.2 ^{o}C by taking surface water readings at the same time that pumped temperature readings were being taken from 0 m.

Dry weight - duplicate subsamples were drawn from the sediment pumped from the bags on site, on four occasions. Duplicate sets of analyses were run on both subsamples, with the result that a precision for both field and lab sample handling was assessed as V = $\pm$ 14% (n=16). Blanks were well below the significant level of weights recorded for the samples. Accuracy was not assessed.

Particulate organic carbon and nitrogen - this procedure has been previously tested for precision for sea water particulates with the following results: V_C = $\pm$ 6% (n=18), V_N = $\pm$ 6% (n=20 using duplicates; LOD = 5 μgC L^{-1}, 2 μgN L^{-1} (n=10). Precision of sediment subsampling and analysis was conducted as for dry weights, with the result that V_C = $\pm$ 8.2% and V_C = $\pm$ 11% (n=14). Accuracy is apparently good, as two samples of Prudhoe Bay crude oil were weighed and found to contain 85 $\pm$ 1% C, 13 $\pm$ 2% H and 0.6 $\pm$ 0.1% N, for a total recovery of 99 $\pm$ 3%. A previous test of combustion temperatures (750 vs 950 ^{o}C) yielded 100 $\pm$ 5% C and 93 $\pm$ 9% N at the lower temperature (n=4 at each temperature).

^{14}C tracer measurements: a) suspended particulates - precision is inferred from data collected on Aug. 4, when the crude oil dispersion was evenly distributed throughout the bag. In this case, V = $\pm$ 2.8% for the 7 samples collected that day. LOD = 12 dpm L^{-1} and accuracy is inferred from the observation that 104% of the ^{14}C was found in the particulate phase (by integrating results from discrete depths over the upper 13 m of the water column) and none in any other pool the day after the tracer addition. b) ^{14}C sedimentation - at 100 dpm mL^{-1}, V = $\pm$ 10% (n=3), LOD = 6 dpm mL^{-1} (n=4). Quenching in these samples may cause under-evaluation of the role of sedimentation in removing ^{14}C from the water column. No definitive assessment of this could be made, although alternate approaches to assessing ^{14}C in sedimented material did show the danger of this error. c) CO_2 - recovery of standard additions of $NaH^{14}CO_3$ were equal to 104 $\pm$ 11%

from sea water (n=6). LOD = 24 dpm L^{-1} (n=4). Daily changes in the procedure may account for some of the observed fluctuations in the data, as the ruggedness of the procedure was not tested. Precision from the 7 samples on any given day should be better than $\pm$ 10%, the coefficient of variation for the sample set from August 1 (n=7). d) extractable dissolved organic carbon - recovery of standard additions of ^{14}C labelled n-hexadecane = 102 $\pm$ 6% (n=2). LOD = 12 dpm L^{-1} (n=3). The accuracy of this technique is dependent on an understanding of what is being recovered by dichloromethane extraction. Polar hydrocarbons which are water soluble will not be extracted, for example. e) chemical fractionation - between days 3 and 12, greater than 92% of the activity was recovered from the four fractions, in comparison to the particulate ^{14}C analyses (n=5). The accuracy of the separations was not tested. LOD = 2 dpm L^{-1} (n=3).

^{15}N uptake rates - V_{NH4} = 8% (n=84), V_{NO3} = $\pm$ 20% (n=80), LOD = 0.01 x 10^{-2} h^{-1}. Underestimates of specific uptake rates result if detrital N is a significant component of the sample. However, absolute uptake rates (PON x specific uptake) are independent of detritus.

Bacteria numbers - at 10^6 cells mL^{-1}, s = $\pm$ 0.1 x 10^6 cells mL^{-1} (n=22), with 22 fields counted per sample). LOD = 10^2 cells mL^{-1} and depends on the volume of water filtered. Accuracy is not readily assessable, however, bacterial production and increase in bacterial numbers agree within about 5% for a short period in CEE 3 when there was apparently no grazing or sedimentation of bacteria.

Bacteria size distribution - fixation by glutaraldehyde or formalin and critical point drying may cause shrinkage of particulate matter, thus affecting the estimates of size and volume.

Phytoplankton and zooplankton counts - assuming a Poisson distribution, then examples of counting error are as follows:

35 organisms, the range = 24 to 49

100 organisms, the range = 82 to 120

This is discussed further in Parsons *et al.* (1984). Some organisms will

not survive fixation especially in formalin, and therefore will not be observed. The ctenophore Bolinopsis sp. is an example.

Relative heterotrophis uptake - at 0.05 ug glucose L^{-1} h^{-1}, CI = $0.006/n^{1/2}$ ug glucose L^{-1} h^{-1}, where n=1 for this study. LOD = 0.01 ug glucose L^{-1}. No blanks were run with this data set. Accuracy is not readily accessable.

Vertical light extinction - Sp = $\pm$ 20 μE m^{-2} h^{-1} for 12 pairs of surface irradiation measurements ranging from 200 to 1000 μE m^{-2} h^{-1}. Accuracy was not assessed.

Size distribution of particles - from the manufacturer, Coulter Electronics; at 2000 counts s = $\pm$ 65 counts, 200 counts s = $\pm$ 12, 70 counts s = $\pm$ 11 and 30 counts s = $\pm$ 8. Coincident counts exceed 10% at 10,000 particles mL^{-1}.

Sinking rates of particles - at 1.8 m d^{-1}, CI = $\pm$ $0.13/n^{1/2}$ m d^{-1}, where n=1 for this study. Range = 0.5 to 50 m d^{-1} (see Parsons et al., 1984).

Photographs and electron micrographs - see bacteria size distribution.

Filterable oil concentrations, gravimetric analyses:

Limit of detection (LOD):

LOD (IUPAC, k=3) = 0.019 mg (n=7); V = $\frac{s_B}{\bar{x}}$ x 100% = 24% (n=7). Each of the 7 procedural blanks consisted of a filter paper wetted with hydrocarbon-free distilled water. Each blank was treated as an actual sample in a batch containing 6 samples. For integrated water samples of a filtered volume of 3.5 L, the LOD for oil on the filter paper was calculated to correspond to a water concentration of 5.4 μg/L and for discrete water samples of 0.5 L, a concentration of 38 μg/L.

Bias:

Caustic digestion is the current method of choice for recovering oil from organic matrices and is generally considered to approach 100%. For this study, an estimate of bias arising from inefficient recovery of oil was made using 2 groups of 3 oil-spiked filter papers and therefore does not reflect on the efficiency of extraction of the oil from the

organic matrix. Nominal amounts of about 1.5 mg and 15 mg of unweathered Prudhoe Bay crude oil for the first and second group, respectively, were used to assess the importance of the amount of oil on recovery.

Evaporative loss through weathering over 2 days at room temperature for the first group was 41.4 $\pm$ 3.7% (n=3) and for the second group, 27.5 $\pm$ 2.8% (n=3). Since the particulate oil obtained from the experiment was already extensively weathered prior to collection, additional loss on storage through evaporation was considered to be unlikely, particularly considering that the filter papers were preserved in the frozen state in an aluminum foil package.

Loss of oil through the caustic treatment and work-up of the pre-weathered oil was determined for each oiled filter paper that was previously used in the evaporative loss experiment. The mean difference d in the case of the first group was -0.033 mg having a standard deviation s_d of 0.081 mg. The decrease was not significant at the 95% confidence level, not even at the 50% confidence level for that matter. For the second group, the mean difference, $d \pm s_d$ (n=3) = - 0.26 $\pm$ 0.63(n=3), was also not significant. Although a statistically significant mean loss could probably be demonstrated by doing a large number of replicates, from a practical standpoint the loss was not of significant magnitude to be of analytical importance. In terms of extraction efficiency, 95 $\pm$ 8% (n=3) of the oil was recovered from the first group of oiled filter papers and 97 $\pm$ 6% (n=3), from the second.

Precision:

Because the amount of residual oil remaining on the filter papers following weathering differed slightly in each group, the method standard deviation cannot be calculated in the usual manner. Thus, s_d is used as an estimate of s. (Note that $s_d = s$ for equal initial amounts and s_d should be insensitive to small differences in initial amounts.)

The coefficients of variation of the method from $V = \frac{s_d}{\bar{x}} \times 100\%$ were 8.1% and 6.6%, respectively, for the first and second groups of oil-spiked papers. The apparent constancy of V for amounts differing by an order of magnitude suggested that the errors were not independent of the amount of

oil present, but increased linearly as a function of the mean.

The precision of a method is best determined by performing replicate analyses at several concentrations of amounts that span the range to be analysed. The standard error of the estimate may then be determined through regression and the requirement for having replicates of differing amounts or concentrations is relaxed. For the present data, which are admittedly sparse, the coefficient of variation seems to be constant so that regression on the log transformed variables is indicated to be appropriate.

The standard error of the estimate from linear regression of the log transformed variables is 0.073. The standard errors corresponding to nominal amounts of 1 mg and 10 mg are 0.042 and 0.043, respectively. Given that the errors are lognormally distributed so that for the above nominal amounts the coefficients of variation of the untransformed variables would be nearly equal to the standard deviation of the log transformed variables, the standard error of the estimate, 7.3%, should approximate V. It is indeed comparable to the estimates of V above.

Oil fluorescence profiles

The oil fluorescence profiles are only semi-quantitative. They provide a continuous record of oil concentration with depth during sampling periods and a record of the change in oil distribution with depth from sampling period to sampling period. Since fluorescence arises from oil components that are in the solution as well as those in particles and since the former are generally also the components that are relatively volatile, the fluorescent response would be expected to diminish in time with transfer of volatiles to the atmosphere. Measurement of the fluorescent response/unit weight for oil recovered from the enclosures in the particulate phase indicates that as the experiment progressed and volatile oil was lost to the atmosphere, the fluorescence observed could have resulted in an underestimate by about 1/2 of the concentration of oil present. Biological oxidation and photooxidation of aromatic constituents, furthermore, could lead either to an additional loss of fluorescence or to a gain in fluorescence depending on the nature of

products and their rate of formation and removal.

Carbohydrate:

Duplicate analyses were carried out in batches with each batch including a duplicate blank. All members of a batch were analysed within a working day. Batches for dissolved total carbohydrate (monosaccharide + polysaccharide) and batches for dissolved monosaccharide for a given set of samples were analysed simultaneously.

Limit of detection and precision:

- particulate polysaccharide: LOD (IUPAC, k=3) = 0.15 mg L^{-1} (based on pooled variances for 3 duplicate determinations); precision: s = 0.11 mg L^{-1} (based on pooled variances for 27 duplicate determinations)
- dissolved monosaccharide: LOD (IUPAC, k=3) = 0.28 mg L^{-1} (based on pooled variances for 7 duplicate determinations); precision: s = 0.077 mg L^{-1} (based on pooled variances for 30 duplicate determinations
- total dissolved carbohydrate (monosaccharide + polysaccharide): LOD (IUPAC, k=3) = 0.19 mg L^{-1} (based on pooled variances for 31 duplicate determinations)
- dissolved polysaccharide: LOD=0.34 mg L^{-1} ($LOD^2_{poly} = LOD^2_{poly+mono} + LOD^2_{mono}$); precision: s = 0.13 mg L^{-1} ($s_{poly} = s_{poly+mono} + s_{mono}$).

Bias:

Glucose was the cabohydrate standard used and therefore all carbohydrate concentrations are given in glucose equivalents. Actual concentrations are not likely to differ by more than a factor of two. The composition of carbohydrate may have changed throughout the period of the experiment. Once again, however, at the very worst a bias factor of greater than 2 from the determined concentrations and greater than 4 between any two concentrations is expected to be highly unlikely.

REFERENCES

Armstrong, F.A.J., C.R. Stearns and J.D.H. Strickland, 1967. The measurements of upwelling and subsequent biological processes by means of the Technicon AutoAnalyzer™ and associated equipment. Deep Sea Res. 14: 381-389.

Cochlan, W.P., 1982. Uptake and regeneration of nitrogen on the Scotian Shelf. M. Sc. Thesis, Dept. of Oceanogr. Dalhousie Univ., Halifax, N.S. 111 pp.

Dugdale, R.C. and J.J. Goering, 1967. Uptake of new and regenerated forms of nitrogen in primary productivity. Limnol. Oceanogr. 12: 196-206.

Fiedler, R. and G. Proksch, 1975. The determination of nitrogen-15 by emission and mass spectrometry in biochemical analysis: a review. Anal. Chim. Acta. 78: 1-62.

Fuhrman, J.A. and F. Azam, 1982. Thymidine incorporation as a measure of heterotrophic bacterioplankton production in marine surface waters: Evaluation and field results. Mar. Biol. 66: 109-120.

Garrett, W.D., 1965. Collection of slick forming materials from the sea surface. Limnol. Oceanogr. 10: 602-605.

Geesey, G.G., R. Mutch and J.W. Costerton, 1978. Sessile bacteria: an important component of the microbial population in small mountain streams. Limnol. Oceanogr. 23: 1214-1223.

Grice, G.D. and M.R. Reeve, 1982. Introduction and description of experimental ecosystems. In Marine Mesocosms. (Grice, G.D. and M.R. Reeve, Eds.). Springer-Verlag, 1-10.

Hager, S.W., L.I. Gordon and P.K. Park, 1968. A practical manual

for the use of the Technicon AutoAnalyser in seawater nutrient analyses. Tech. Rept. , 68-33, Dept. of Oceanogr. Oregon State University, Corvallis, 31 pp.

Hobbie, J.E., R.J. Daley and S. Jasper, 1977. Use of nuclepore filters for counting bacteria by fluorescence microscopy. Appl. Environ. Microbiol. , 33: 1225-1228.

Iseki, K., M. Takahashi, E. Bauerfeind and C.S. Wong, 1981. Effects of polychlorinated biphenyls (PCBs) on a marine plankton population and sedimentation in controlled ecosystem enclosure. Mar. Ecol. Prog. Ser. 5, 207-214.

Koroleff, F., 1970. Information, techniques and methods for seawater analysis. Interlab. Rept. , No. 3, 19-22.

La Roche, J., 1983. Ammonium regeneration: its contribution to phytoplankton nitrogen requirements in a eutrophic environment. Mar. Biol., 75: 231-240.

Lewis, E.L., 1980. The practical salinity scale 1978 and its antecendents. IEEE Journal of Oceanic Engineering OE-5(1).

Li, W.K.W., H.E. Glover, and I. Morris, 1980. Physiology of carbon photoassimilation by Oscillatoria thiebautii in the Caribean Sea. Limnol. Oceanogr. 25: 447-456.

Lund, J.W.G., C. Kipling and E.D. LeCren, 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydrologia , 11: 142-170.

Menzel, D.W. and J. Case, 1977. Concept and design: controlled ecosystem pollution experiment. Bull. Mar. Sci., 27: 1-7.

Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta, 27: 31-36.

Parsons, T.R., Y. Maita and C.M. Lalli, 1984. A manual for biological and chemical methods for sea water analysis. Pergamon Press (Oxford, England).

Parsons, T.R., P.J. Harrison, J.C. Acreman, H.M. Dovey, P.A. Thompson, P.M. Lalli, K. Lee, Li Guanguo and Chen Xiaolin, (in press). An experimental marine ecosystem response to crude oil and corexit 9527. Part II: Biological effects. Mar. Environ. Res. , 13.

Slawyk, G. and J.J. MacIsaac, 1972. The comparison of two automated ammonium methods in a region of coastal upwelling. Deep Sea Res. 19, 521-524.

Steele, J.H., D.M. Farmer and E.W. Henderson, 1977. Circulation and temperature structure in large marine enclosures. J. Fish. Res. Board Can. 34, 1095-1104.

Strickland, J.D.H. and T.R. Parsons, 1972. A practical handbook of sea water analysis. Fish. Res. Board Can. Bull. , 167.

Whitney, F.A., K. Perry, C. Philpott, A. Ramey, and C.S. Wong, 1981. Pentachlorophenol in a pelagic marine ecosystem: effects on the ecosystem. Pac. Mar. Sci. Rept., 81-83.

Wong, C.S., F.A. Whitney, W.J. Cretney, K. Lee, F. MacLaughlin, Jinping Wu, Tianbo Fu and Dongfa Zhuang, (in press). An experimental ecosystem response to crude oil and Corexit 9527: Part I - fate of chemically dispersed crude oil. Mar. Environ. Res. , 13.

FIELD LOG

Seafluxes 83-SF-01

Prudhoe Bay crude oil and dispersant

17 July	0600	Divers and topside personnel loaded boats and proceeded to the experimental site in Pat Bay.
	0700	3 bags were lowered into the water, then raised to the surface by SCUBA diver teams. Each bag appeared 70 to 80% full.
	1300-1500	Bags were filled by bucketting surface water into them.
	1700	The enclosed sea water was enriched with nutrients between 0 and 13 m in each CEE (10:10:1 μmol L^{-1} of NO_3:SIO_3:PO_4).
18 July	0845	Sampled CEEs 1, 2 and 3 by pumping water from 0-5, 5-10 and 10-13 m intervals.
	1000	Started incubations of $NAH^{14}CO_3$, ^{15}N-NO_3 and NH_4, ^{14}C-glucose and ^{3}H-thymidine spiked samples.
	1100	Salinities and temperatures taken by pumping water water from fixed depths. Settled materials were pumped from the bottom of each CEE and zooplankton tows were taken between 13 and 0 m.
19 July	1500	Added 20 g Corexit to CEE 2 between 2 and 4 m. CEE 3 received 200 g Prudhoe Bay crude oil mixed with 20 g Corexit and 125 μCi ^{14}C labelled n-hexadecane, dispersed between 2 and 4 m. A light oil slick appeared on the surface of the CEE shortly after the oil addition was made.
20 July	0830	Sampling as on July 18. Fluorometric profiles were taken in bag 3, as were samples for ^{14}C tracer analyses. A tear in the hose used to remove settled material from CEE 2 resulted in the loss of sediment and about 25% of this bag's water.
21 July	1500	Replaced the broken hose on CEE 2. Sampled the oil slick on CEE 3 with a wire mesh screen.
22,24,26,29 July and 1,4 August		Continued sampling as on July 20.
10 August		Less detailed sampling of the CEEs.
25 August		Removed sediment from CEE 3 and took a section of the bag wall for hydrocarbon analysis.

TABLE 1 a: NO_3 & NO_2 µM

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	22.0	17.0	.330	.210	.200	.190	.360	0
5-10	26.7	29.3	15.0	.110	.350	0	.150	.100
10-13	25.8	29.8	23.9	14.4	.880	1.18	.840	.350
AVE:								
0-13	24.7	24.7	11.4	3.45	.415	.345	.390	.119
BAG#2								
DEPTH								
0-5	22.2	16.6	.330	.080	.200	.090	.060	0
5-10	23.1	24.8	8.83	.890	.260	.090	.060	0
10-13	22.1	25.5	16.8	7.02	.320	.160	.060	0
AVE:								
0-13	22.5	21.8	7.40	1.99	.251	.106	.060	0
BAG#3								
DEPTH								
0-5	26.0	24.1	19.4	15.7	11.3	4.86	0	0
5-10	20.8	23.5	20.7	18.4	14.8	13.5	3.05	2.87
10-13	22.0	23.7	22.1	21.5	17.9	15.1	11.8	7.86
AVE:								
0-13	23.1	23.8	20.5	18.1	14.2	10.5	3.90	2.92

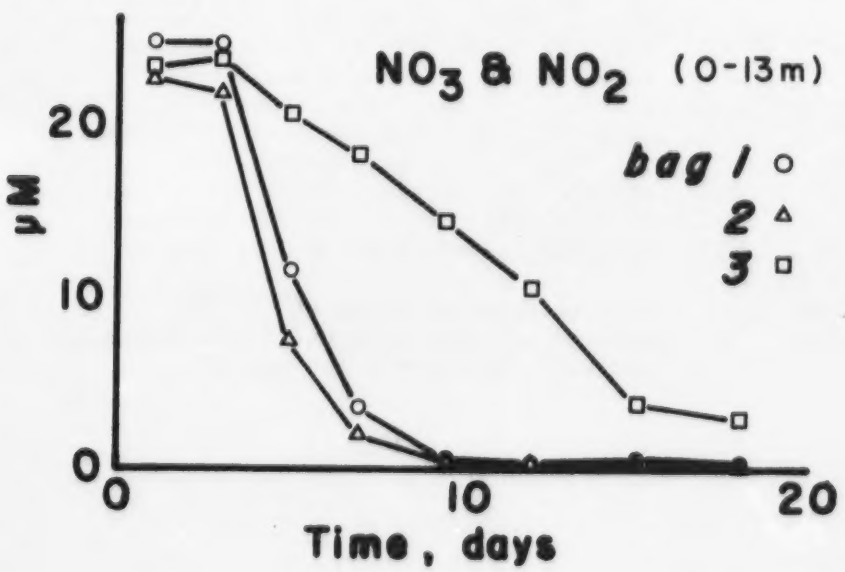


TABLE 1 b: NH_4 µM

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	.600	.520	.350	.370	.290	.550	1.30	.850
5-10	.550	.520	.520	.250	.310	.650	.870	1.86
10-13	.560	.430	.420	.410	.450	.640	1.83	4.21
AVE:								
0-13	.572	.499	.432	.333	.335	.609	1.26	2.01
BAG#2								
DEPTH								
0-5	.360	.460	.410	.280	.250	.690	.760	.620
5-10	.360	.450	.530	.950	.270	.620	.770	1.59
10-13	.360	.450	.480	.940	.270	.600	1.18	3.58
AVE:								
0-13	.360	.454	.472	.690	.262	.642	.861	1.68
BAG#3								
DEPTH								
0-5	.410	.450	.260	.970	.770	.230	.210	.290
5-10	.350	.450	.240	1.47	.560	.260	.210	.530
10-13	.540	.510	.280	.840	.570	.670	.290	.940
AVE:								
0-13	.417	.464	.257	1.13	.643	.343	.228	.532

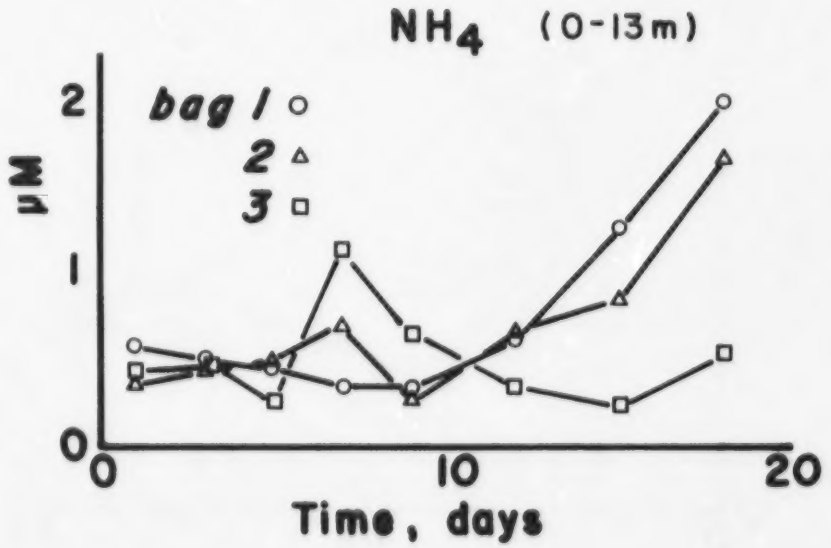


TABLE 1 c: PO_4 µM

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	2.71	2.76	1.09	.620	.480	.820	.960	.950
5-10	2.92	3.48	2.16	.950	.610	1.04	1.14	1.34
10-13	2.81	3.49	2.76	2.23	1.46	1.38	1.52	1.72
AVE:								
0-13	2.81	3.21	1.89	1.12	.756	1.03	1.16	1.28
BAG#2								
DEPTH								
0-5	2.83	2.75	1.21	.590	.610	1.09	1.12	.910
5-10	2.65	3.07	1.79	1.02	.730	1.03	1.10	1.27
10-13	2.55	3.08	2.28	1.93	1.10	1.17	1.33	1.59
AVE:								
0-13	2.70	2.95	1.68	1.06	.769	1.09	1.16	1.21
BAG#3								
DEPTH								
0-5	3.10	3.17	2.35	2.31	1.87	1.27	.550	.610
5-10	2.41	2.83	2.37	2.52	2.09	2.05	2.14	1.13
10-13	2.54	2.82	2.24	2.46	2.30	2.27	1.39	1.63
AVE:								
0-13	2.71	2.96	2.33	2.43	2.05	1.80	1.36	1.05

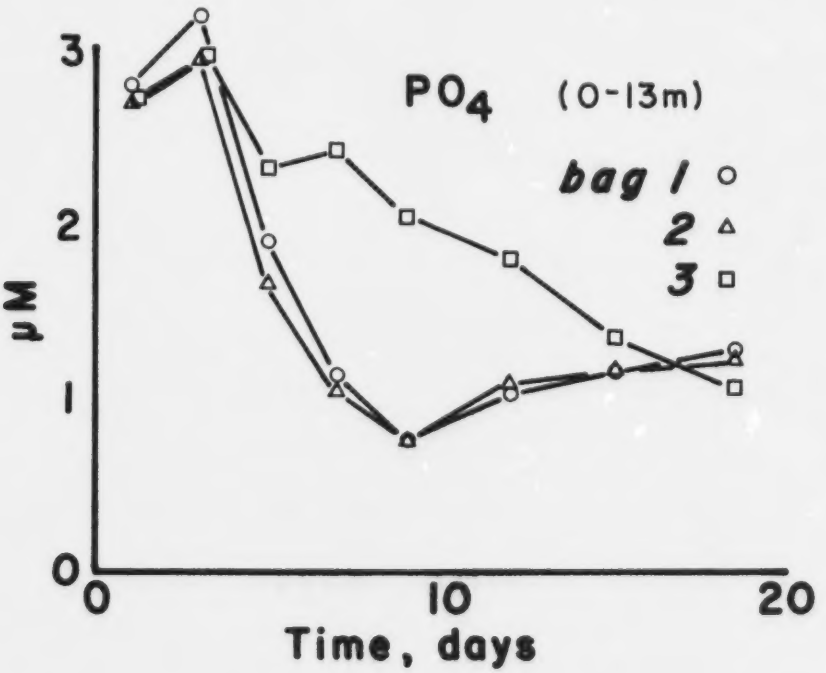


TABLE 1 d: SiO_4 µM

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	46.0	31.3	8.30	1.61	1.76	1.89	1.70	1.55
5-10	54.3	40.6	29.8	6.59	3.53	2.49	2.55	2.89
10-13	54.5	41.1	37.7	30.8	7.06	3.98	3.77	4.23
AVE:								
0-13	51.2	37.1	23.4	10.3	3.66	2.60	2.50	2.68
BAG#2								
DEPTH								
0-5	45.4	30.7	10.0	1.61	1.59	1.39	3.79	1.29
5-10	51.0	37.9	24.5	5.39	2.82	2.14	4.35	2.41
10-13	49.4	38.7	31.6	23.5	5.18	2.52	5.20	3.43
AVE:								
0-13	48.5	35.3	20.6	8.12	2.89	1.94	4.33	2.21
BAG#3								
DEPTH								
0-5	45.3	34.0	34.2	36.9	33.9	21.0	16.1	18.6
5-10	49.8	39.1	36.7	38.9	36.8	29.5	24.1	22.8
10-13	53.2	40.2	38.5	41.0	38.8	30.9	30.2	26.5
AVE:								
0-13	48.9	37.4	36.2	38.6	36.1	26.6	22.4	22.0

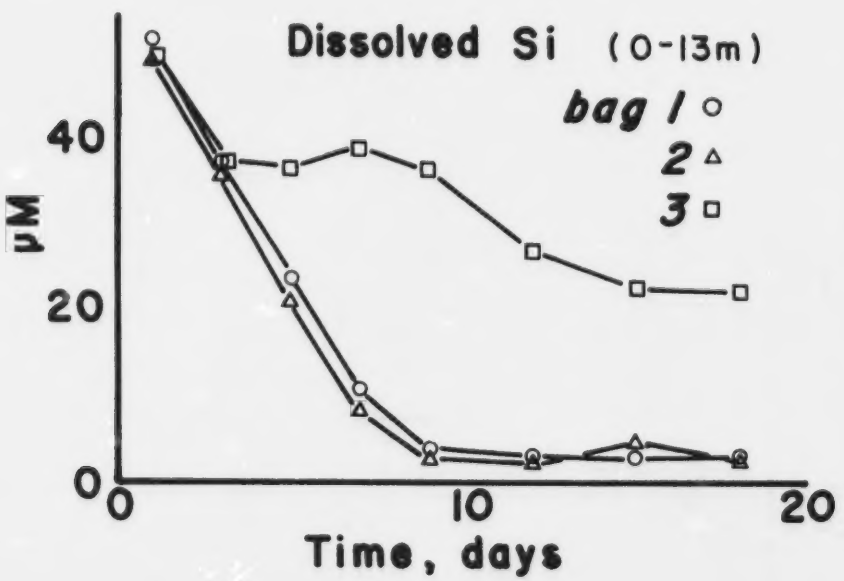


TABLE 2: Chlorophyll *a* mg m^{-3}

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	2.50	7.40	16.2	3.00	3.80	.450	.620	.970
5-10	3.10	2.30	15.5	19.1	15.9	.460	.480	.420
10-13	.820	1.10	6.60	34.1	32.1	.620	.450	.780
AVE:								
0-13	2.34	3.98	13.7	16.4	15.0	.493	.527	.715
BAG#2								
DEPTH								
0-5	1.90	9.10	19.2	7.40	10.4	1.11	.720	1.50
5-10	.730	3.30	19.1	13.0	14.7	.560	.610	.810
10-13	.540	1.70	12.1	30.9	22.6	.710	.390	.390
AVE:								
0-13	1.14	5.16	17.5	15.0	14.9	.806	.602	.978
BAG#3								
DEPTH								
0-5	1.70	7.30	4.20	4.60	6.20	5.70	4.80	2.90
5-10	.550	2.60	5.80	5.70	5.90	5.60	11.6	4.80
10-13	.540	1.20	2.90	5.10	5.40	5.90	9.00	4.00
AVE:								
0-13	.990	4.08	4.52	5.14	5.90	5.71	8.38	3.88

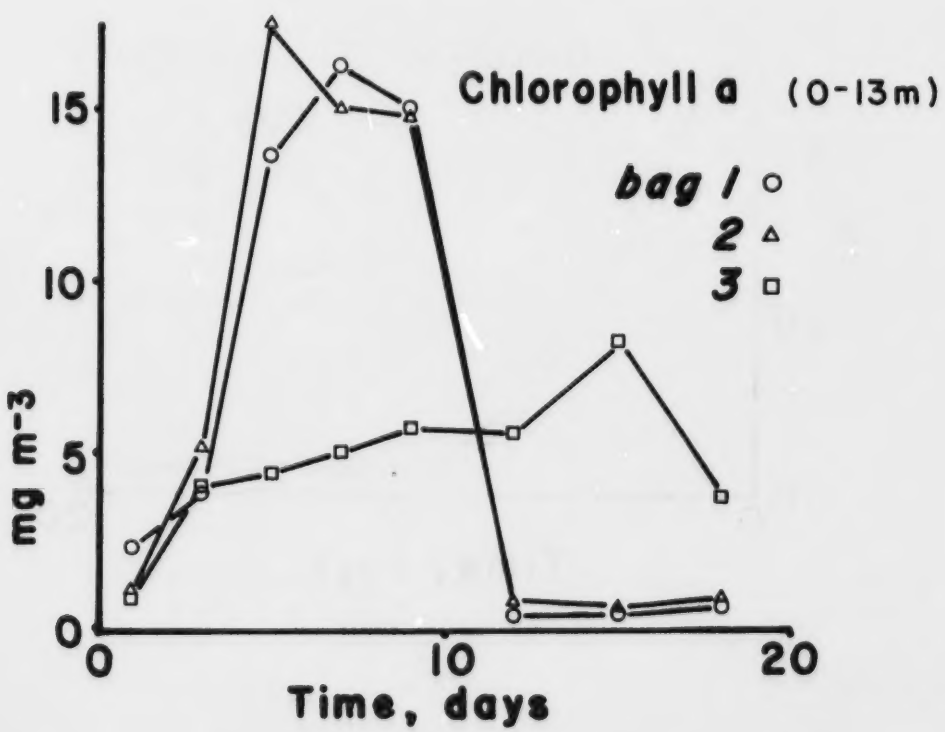


TABLE 3: Primary Production mg C m^{-3} h^{-1}

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0-5	7.56	23.2	36.5	.180	6.42	1.30	3.11	4.62
5-10	1.17	1.58	9.74	17.0	11.0	.570	.300	.780
10-13	.290	.740	.570	3.05	1.86	.890	.550	.590
AVE:								
0-13	3.42	9.69	17.9	7.31	7.11	.925	1.44	2.21
BAG#2								
DEPTH								
0-5	10.4	25.1	24.6	9.01	8.83	4.94	3.46	5.80
5-10	.750	2.69	8.29	6.30	9.75	.500	.670	.440
10-13	.590	.490	3.84	1.40	1.81	.240	.130	.160
AVE:								
0-13	4.41	10.8	13.5	6.21	7.56	2.15	1.62	2.44
BAG#3								
DEPTH								
0-5	8.79	3.76	1.98	3.36	8.41	11.2	17.7	1.00
5-10	1.45	1.10	1.62	2.61	2.46	5.52	8.29	2.72
10-13	.820	.610	4.09	1.09	1.16	2.75	1.08	1.30
AVE:								
0-13	4.13	2.01	2.33	2.55	4.45	7.05	10.3	1.73

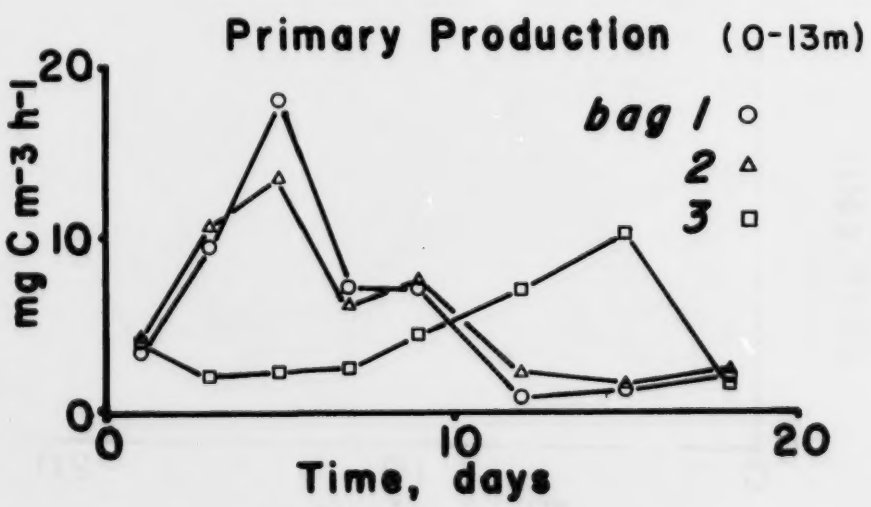


TABLE 4: Bacterial Productivity cells L^{-1} h^{-1} ($x10^6$)

	DATE								
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	18	20	22	24	26	29	1	4	10
BAG#1									
DEPTH									
0-5	31.0	24.7	30.0	58.7	38.2	12.4	2.98	71.1	34.8
5-10	6.47	3.62	9.09	43.6	56.4	8.31	16.1	28.0	14.9
10-13	4.99	4.32	4.36	32.4	55.8	10.4	16.8	46.0	26.3
AVE:									
0-13	15.6	11.9	16.0	46.8	49.3	10.4	11.2	48.7	25.2
BAG#2									
DEPTH									
0-5	35.6	45.2	63.5	56.4	82.3	15.1	11.9	32.3	31.4
5-10	8.31	6.96	18.6	45.4	80.3	9.68	13.4	9.47	22.5
10-13	5.19	4.38	13.2	28.0	64.5	15.7	15.5	11.7	31.5
AVE:									
0-13	18.1	21.1	34.6	45.6	77.4	13.2	13.3	18.8	28.0
BAG#3									
DEPTH									
0-5	29.3	42.3	45.0	72.5	48.1	31.7	23.4	20.1	72.9
5-10	7.96	7.92	20.4	46.7	30.9	12.7	11.6	10.4	56.6
10-13	5.98	8.30	12.9	21.0	16.5	16.9	10.6	9.32	74.8
AVE:									
0-13	15.7	21.2	28.1	50.7	34.2	21.0	15.9	13.9	67.1

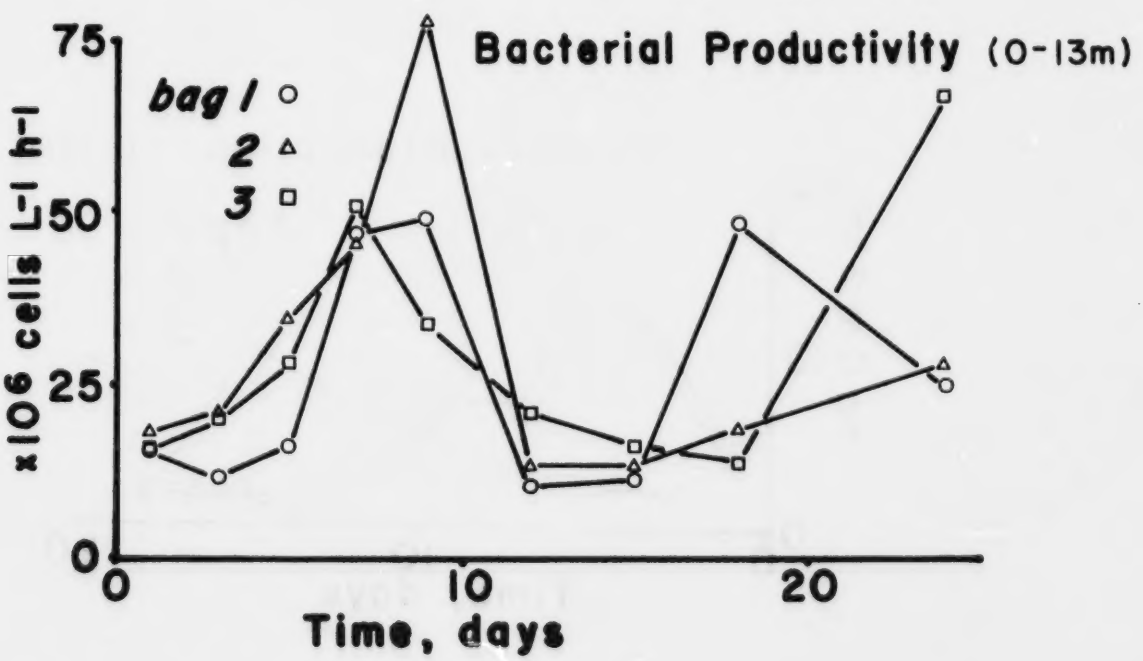


TABLE 5 Oil Concentrations in Bag # 3

Date, MO: / DY:	JUL 20	JUL 22	JUL 24	JUL 26	JUL 29	AUG 1	AUG 4	AUG 10	AUG 25
Particulate Oil mg L^{-1}									
0-5 m	4.23	2.77	2.15	1.32	0.18	0.12	0.08	0.05	
5-10 m	0.13	1.17	1.25	1.07	0.34	0.16	0.10	0.09	
10-13 m	0.01	0.32	0.43	0.58	0.45	0.27	0.08	0.09	
Total Non-Volatile Oil mg L^{-1}									
3 m	4.53	2.83	2.00	1.43	0.38	0.55	0.20	-	
6 m	1.58	1.98	1.74	1.03	0.50	0.38	0.40	-	
Sedimented Oil									
Rate, mg d^{-1}	6.5	30	125	864	5975	4721	1207	526	124
Sum, g	.013	.073	.322	2.05	20.0	34.1	37.8	40.9	42.8

Oil associated with slick on bag wall, 10 cm above to 10cm below the water line, on Aug. 25 = 4.1 ± 0.8 g (n=3).

OIL PROFILES

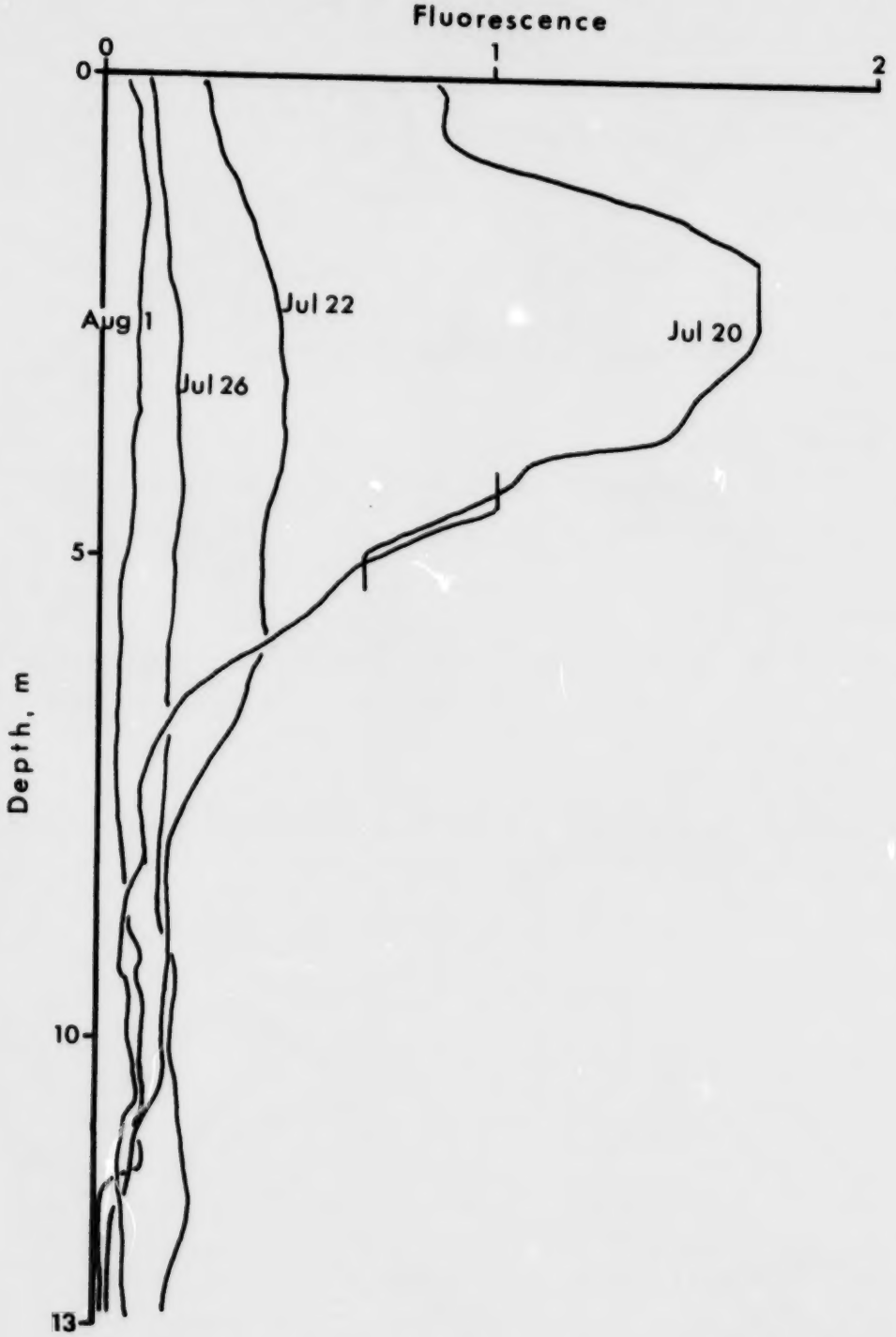


TABLE 6 Vertical Extinction of Light $\mu E\ m^{-2}\ s^{-1}$

Depth(m)	Bag # 1	Bag # 2	Bag # 3
19 July, 1983			
0	210-200	215-210	215-215
3	35	39	45
5	21	19.5	21.7
7	9.5	12.0	12.5
10	4.6	5.5	5.7
13	2.5	2.6	2.7
21 July, 1983			
0	1000-985	860-900	800-960
1	470	450	260
2	140	90	56
3	50	50	18
5	24	-	11
7	15	28	-
26 July, 1983			
0	650-680	750-720	640-620
1	420-480	510-490	200-180
2	170	180	68
5	62	45	14
7	31	29	9.7
10	10	10	5.7
28 July, 1983			
0	550-450	320-320	280-300
1	180	120	90
2	120	52	37
5	53	27	13
7	34	19	9.5
10	20	10	5.0

Measurements are of Photosynthetically Active Radiation (PAR)

TABLE 7: Salinity °/oo

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0	28.854	28.900	28.930	28.961	28.993	28.948	29.023	29.075
5	29.064	29.062	29.004	28.990	28.994	29.015	29.016	29.034
10	29.113	29.103	29.086	29.083	29.060	29.045	29.038	29.036
13	29.124	29.106	29.100	29.085	29.083	29.050	29.050	29.038
BAG#2								
DEPTH								
0	28.839	28.879	28.912	28.951	28.971	28.923	28.989	29.052
5	29.020	28.990	28.944	28.948	28.971	28.940	28.978	28.985
10	29.055	29.046	29.002	28.996	28.982	28.981	28.976	28.978
13	29.066	29.051	29.027	29.012	29.000	28.978	28.980	28.977
BAG#3								
DEPTH								
0	28.856	28.898	28.966	28.997	29.021	28.990	29.047	29.078
1	28.854	28.909	28.964	28.993	29.022	28.996	29.046	29.079
3	28.907	28.940	28.970	28.991	29.022	29.000	29.038	29.050
5	29.005	29.015	28.998	29.002	29.022	29.023	29.023	29.033
7	29.034	29.065	29.026	29.016	29.023	29.027	29.026	29.029
10	29.045	29.078	29.061	29.051	29.040	29.037	29.030	29.031
13	29.116	29.096	29.076	29.062	29.054	29.033	29.033	29.029

TABLE 8: Temperature (^{o}C)

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
BAG#1								
DEPTH								
0	15.2	15.3	15.1	15.7	16.3	15.8	16.7	17.4
5	13.5	14.6	14.3	14.7	16.2	14.1	14.9	14.9
10	12.4	13.8	13.5	13.5	14.2	13.3	13.4	13.4
13	12.1	13.3	13.3	13.4	13.5	13.1	13.0	13.1
BAG#2								
DEPTH								
0	15.3	15.3	15.2	15.7	16.3	15.8	16.7	17.5
5	13.6	14.6	14.3	15.1	16.2	14.1	15.4	14.9
10	12.4	13.8	13.6	13.5	14.2	13.3	13.5	13.3
13	12.2	13.3	13.4	13.3	13.5	13.0	13.0	13.1
BAG#3								
DEPTH								
0	15.5	15.4	15.6	15.9	16.3	16.1	16.9	17.8
1	15.2	15.0	15.3	15.7	16.3	15.8	16.8	17.6
3	14.7	14.8	14.8	15.4	16.3	15.1	16.3	16.4
5	13.7	14.5	14.3	14.8	16.2	14.1	15.0	14.8
7	13.1	14.2	14.0	14.1	15.7	13.6	14.1	14.0
10	12.5	13.8	13.6	13.5	14.1	13.3	13.4	13.4
13	12.2	13.2	13.3	13.4	13.5	13.1	13.0	13.1

TABLE 9 Sedimentation Rates

Date, MO:	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	20	22	24	26	29	1	4	10
Dry Weight $g\ d^{-1}$								
Bag #								
1	1.20	1.63	5.95	22.9	17.8	15.9	21.9	3.03
2	lost	0.67	5.70	15.5	13.7	13.9	19.1	1.98
3	0.89	1.04	1.58	2.41	19.5	23.6	10.5	4.27
Particulate Organic Carbon and Nitrogen $g\ d^{-1}$								
Bag #								
1 C	.166	.276	1.55	4.41	2.60	3.33	3.07	0.853
N	.0185	.0402	.243	.725	.370	.402	.607	.132
2 C	lost	.101	1.99	3.67	2.76	3.25	4.03	.755
N	"	.0163	.309	.610	.371	.442	.607	.122
3 C	.140	.186	.402	1.18	11.2*	14.0*	3.90	.958
N	.0177	.0238	.0368	.0775	.507	.743	.373	.090
					* formalin preserved samples			
Chlorophyll *a* $mg\ d^{-1}$								
Bag #								
1	.415	1.40	19.5	77.5	33.4	37.0	73.7	5.57
2	lost	0.87	25.5	54.5	62.7	56.7	61.3	8.57
3	.289	0.85	2.66	4.65	52.7	61.3	45.3	15.0
Total Sedimentation								
Bag #								
1 D.Wt. (g)	2.39	5.65	17.6	63.4	117	164	230	248
C (g)	.331	.882	3.97	12.8	20.6	30.6	42.8	47.9
N (g)	.0369	.117	.602	2.05	3.16	4.51	6.33	7.12
Chl *a* (mg)	.829	3.63	42.5	198	300	410	631	663
2 D.Wt. (g)	lost	0.56	12.0	42.9	84.0	126	183	195
C (g)	"	.169	4.14	11.5	19.8	29.5	41.6	46.1
N (g)	"	.0272	.645	1.87	3.01	4.34	6.16	6.89
Chl *a* (mg)	"	1.44	52.3	161	349	519	703	729
3 D.Wt. (g)	1.78	3.86	7.01	11.8	70.3	141	173	198
C (g)	.280	.653	1.46	3.81	37.4	79.3	91.0	96.8
N (g)	.0353	.0828	.156	.311	1.83	4.06	5.18	5.72
Chl *a* (mg)	.577	2.28	7.59	16.9	175	359	495	540

TABLE 10a: Particulate ^{14}C dpm/L

Suspended

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	20	22	24	26	29	1	4	10
DEPTH (m)								
0	9770	5840	5090	1550	624	378	213	141
1	10,400	6530	4410	1760	612	383	195	209
3	10,200	6430	3630	1710	566	-	206	125
5	7510	5450	4140	1670	515	310	201	137
7	2460	4160	3290	1410	494	384	200	133
10	260	1810	2170	1080	506	334	201	127
13	0	941	975	998	507	318	200	132

Sedimented (x 10^6 = dpm/enclosure)

Pumped Sediment	0.06	0.16	0.54	1.28	11.9	11.0	3.43	2.69
Volume Pumped (L)	19	19	19	19	38	38	38	19

TABLE 10b: Size Fractionation of Particulate ^{14}C dpm/L
(All data from 3 m samples)

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	20	22	24	26	29	1	4	10
>.45 µm	10,200	6430	3630	1710	566	346	206	125
<.45 µm	1	3	11	4	18	40	3	-
>3.0 µm	2500	2050	2510	620	138	106	66	24
<3.0 µm	-	2920	805	450	195	83	13	-
>8.0 µm	1650	560	394	350	38	38	20	18
<8.0 µm	-	5580	4260	368	190	83	13	-

TABLE 10c: $^{14}CO_2$ in Sea Water dpm/L

	DATE							
MO:	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	20	22	24	26	29	1	4	10
DEPTH (m)								
0	13	15	431	2380	2120	1700	1470	2220
1	0	7	402	2090	1480	1590	2210	2030
3	0	4	357	1950	1320	1610	1420	2040
5	0	38	278	1900	944	1420	1400	1840
7	0	43	108	1450	762	1210	1170	1860
10	0	9	102	684	647	1430	1140	1460
13	0	0	21	523	577	1650	1330	2087

TABLE 10d: Dissolved Organic ^{14}C dpm/L

0	1	3	11	4	18	40	2
1	0	1	11	6	20	3	0
3	0	1	3	2	15	5	2
5	0	0	8	0	-	0	0
7	0	0	6	0	7	5	0
10	0	0	6	0	2	5	0
13	0	0	6	0	5	2	0

TABLE 10e: Chemical Fractionation of Particulates dpm/L
(all samples from 0-5 m in Bag 3)

Date	free hydrocarbons/ lipid	small molecular wt. compounds	polysaccharide/ nucleic acid	protein
Jul 20	8873	0	0	37
Jul 22	5712	12	27	34
Jul 24	2394	326	576	543
Jul 26	372	110	336	372
Jul 29	152	29	168	186
Aug 1	63	18	32	105
Aug 4	31	2	64	78
Aug 10	13	9	24	66
Aug 25	3	1	24	13

TABLE 11a Particulate Organic Carbon $\mu g\ L^{-1}$

Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
Bag # 1								
0-5 m	206	447	808	489	414	189	230	263
5-10 m	91.9	140	569	895	648	157	151	126
10-13 m	84.8	112	238	1460	1330	255	140	127
Bag # 2								
0-5 m	223	599	985	749	695	296	315	364
5-10 m	102	174	691	875	764	186	153	113
10-13 m	70.7	111	448	1640	1240	224	140	128
Bag # 3								
0-5 m	214	>>1500	3000	2680	1850	588	712	493
5-10 m	119	245	1340	1780	1520	750	845	584
10-13 m	82.9	123	>250	705	1040	632	616	497

TABLE 11b Particulate Nitrogen $\mu g\ L^{-1}$

Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	1	4
Bag # 1								
0-5 m	43.3	92.4	130	60.5	61.4	37.6	45.1	50.5
5-10 m	18.6	27.2	106	127	101	31.5	29.7	23.5
10-13 m	16.3	18.5	44.8	244	184	53.3	27.7	23.5
Bag # 2								
0-5 m	46.5	79.5	165	90.8	102	61.2	61.6	68.2
5-10 m	19.4	34.8	129	104	117	38.0	29.8	21.9
10-13 m	13.6	18.1	81.9	261	197	44.7	28.0	25.7
Bag # 3								
0-5 m	42.1	452	133	105	108	83.8	85.2	76.7
5-10 m	23.8	33.5	83.8	94.6	90.4	62.6	124	94.6
10-13 m	19.9	22.5	140	42.9	71.4	71.9	84.3	71.4

TABLE 12 a: Specific Nitrate Uptake $x10^{-2}\ h^{-1}$

	DATE				
MO:	JUL	JUL	JUL	JUL	AUG
DY:	18	20	22	29	1
BAG #1					
0-5 m	1.742	1.129	0.648	.0675	.0985
5-10 m	3.523*	2.413	5.525	.0200	.0189
10-13 m	1.213	1.242	2.668	.5643	.0276
BAG #2					
0-5 m	5.508	4.268	0.761	.0575	.0436
5-10 m	0.913*	7.615	0.664	.0230	.0195
10-13 m	3.498*	3.501	6.838	.1345	.0274
BAG #3					
0-5 m	0.477	15.479	24.317	3.798	.230
5-10 m	5.181	3.256*	40.280	3.375	2.287
10-13 m	0.583	2.886*	53.824	5.832	4.002

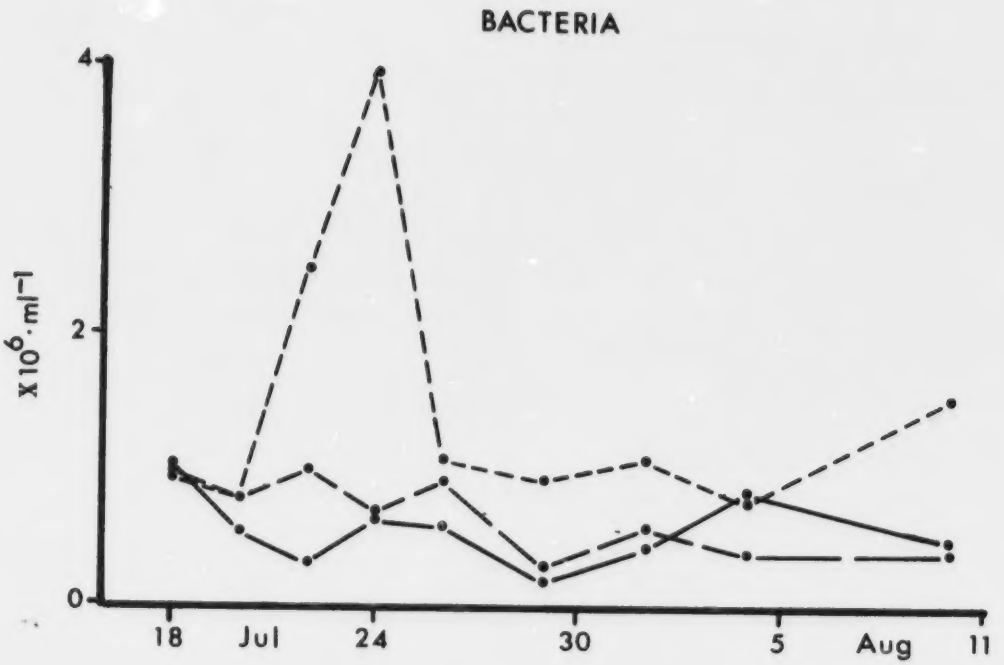
TABLE 12 b: Specific Ammonium Uptake $x10^{-2}\ h^{-1}$

	DATE				
MO:	JUL	JUL	JUL	JUL	AUG
DY:	18	20	22	29	1
BAG #1					
0-5 m	2.265	1.102	0.795	0.568	1.187
5-10 m	1.115	1.366	1.315	0.776	0.405
10-13 m	0.465	0.836*	1.040	0.517	0.287*
BAG #2					
0-5 m	1.403	0.997	0.684	0.671	0.999
5-10 m	1.035	1.400	1.029	0.659	0.612
10-13 m	0.666	1.037	1.344	0.498	0.295
BAG #3					
0-5 m	1.945	1.107	0.040	0.722	0.713
5-10 m	1.240	1.016	0.070	0.936	0.658
10-13 m	0.959	0.931	0.0412	0.577	0.692

* indicates single analysis, all others are averages of duplicates.

TABLE 13 Carbohydrates mg L^{-1}

Date: MO	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG	AUG	AUG
DY	20	22	24	26	29	1	4	4	4	10
BAG#	3	3	3	3	3	3	3	1	2	3
Dissolved monosaccharide mg L^{-1}										
Depth										
0-5 m	0.37	0.30	0.35	0.49	0.33	0.54	0.46	0.89	0.43	0.36
5-10 m	0.27	0.19	0.12	0.32	0.35	0.38	0.36	0.60	0.63	0.35
10-13 m	0.29	0.12	0.11	0.40	0.26	0.33	0.30	0.52	0.40	0.34
Dissolved polysaccharide mg L^{-1}										
Depth										
0-5 m	0.27	0.37	0.22	0.03	0.13	0.04	0.04	0.27	0.64	0.15
5-10 m	0.46	0.39	0.62	0.03	0.63	0.03	0.02	0.23	0.12	0.15
10-13 m	0.28	0.26	0.25	0.01	0.05	0.03	0.18	0.13	0.08	0.13
Particulate polysaccharide mg L^{-1}										
Depth										
0-5 m	0.21	2.18	0.12	0.12	0.31	0.38	0.25			0.11
5-10 m	0.04	0.10	0.18	0.12	0.08	0.28	0.12			0.06
10-13 m	0.05	0.03	7.77	0.06	1.20	0.11	0.06			0.02


BACTERIA
4
2
0
$X10^6 \cdot ml^{-1}$
18
Jul
24
30
5
Aug
11

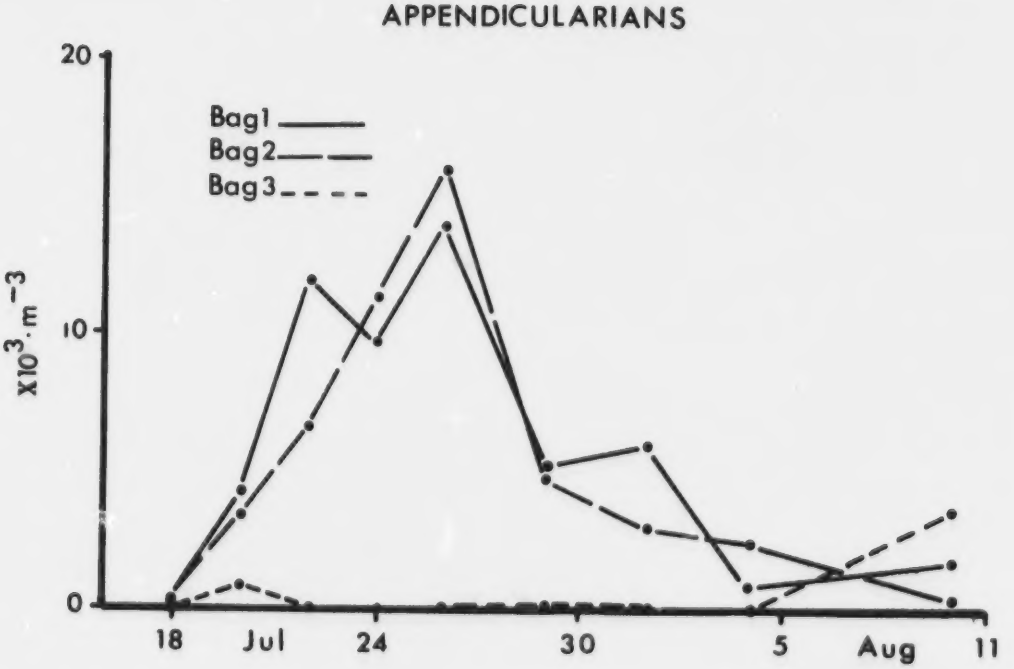

APPENDICULARIANS
20
10
0
$X10^3 \cdot m^{-3}$
Bag1
Bag2
Bag3
18
Jul
24
30
5
Aug
11

TABLE 14 Bacterial Numbers $x10^5$ cells mL^{-1}

Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
DY:	18	20	22	24	26	29	1	4	10
Bag # 1									
0-5 m	13.2	7.08	4.76	6.88	5.79	1.78	3.49	7.81	7.15
5-10 m	10.2	5.51	2.82	6.15	5.97	1.57	4.08	9.68	2.83
10-13 m	8.61	4.96	1.71	6.77	6.82	2.21	6.13	8.41	4.83
Bag # 2									
0-5 m	12.8	10.7	13.6	7.88	7.81	3.52	4.62	4.17	4.33
5-10 m	8.51	6.57	9.31	7.16	10.5	2.79	6.05	4.50	3.96
10-13 m	7.37	5.48	6.33	5.74	9.80	2.96	7.98	3.34	4.02
Bag # 3									
0-5 m	12.1	8.94	31.6	54.9	11.8	12.6	15.4	9.04	20.9
5-10 m	9.1	8.45	25.7	38.5	10.7	7.34	7.99	7.41	10.5
10-13 m	6.5	6.67	12.6	14.9	9.95	8.38	8.61	6.28	13.8

Bacterial Size Distribution

		cocci shaped cells		bacilli shaped cells		mean cell
Date	Bag#	# measured	$\bar{x}$ volume	# measured	$\bar{x}$ volume	volume (μm^3)
Jul 22	1	47	0.059	10	0.166	0.078
Jul 26	1	25	0.128	41	0.188	0.165
Aug 1	1	60	0.090	36	0.228	0.142
Jul 22	2	71	0.102	36	0.177	0.127
Jul 26	2	44	0.090	67	0.190	0.150
Aug 1	2	31	0.113	76	0.125	0.122
Jul 19	3	86	0.109	25	0.138	0.115
Jul 22	3	46	0.108	58	0.233	0.178
Jul 26	3	51	0.082	74	0.180	0.140
Aug 1	3	77	0.294	57	0.181	0.246

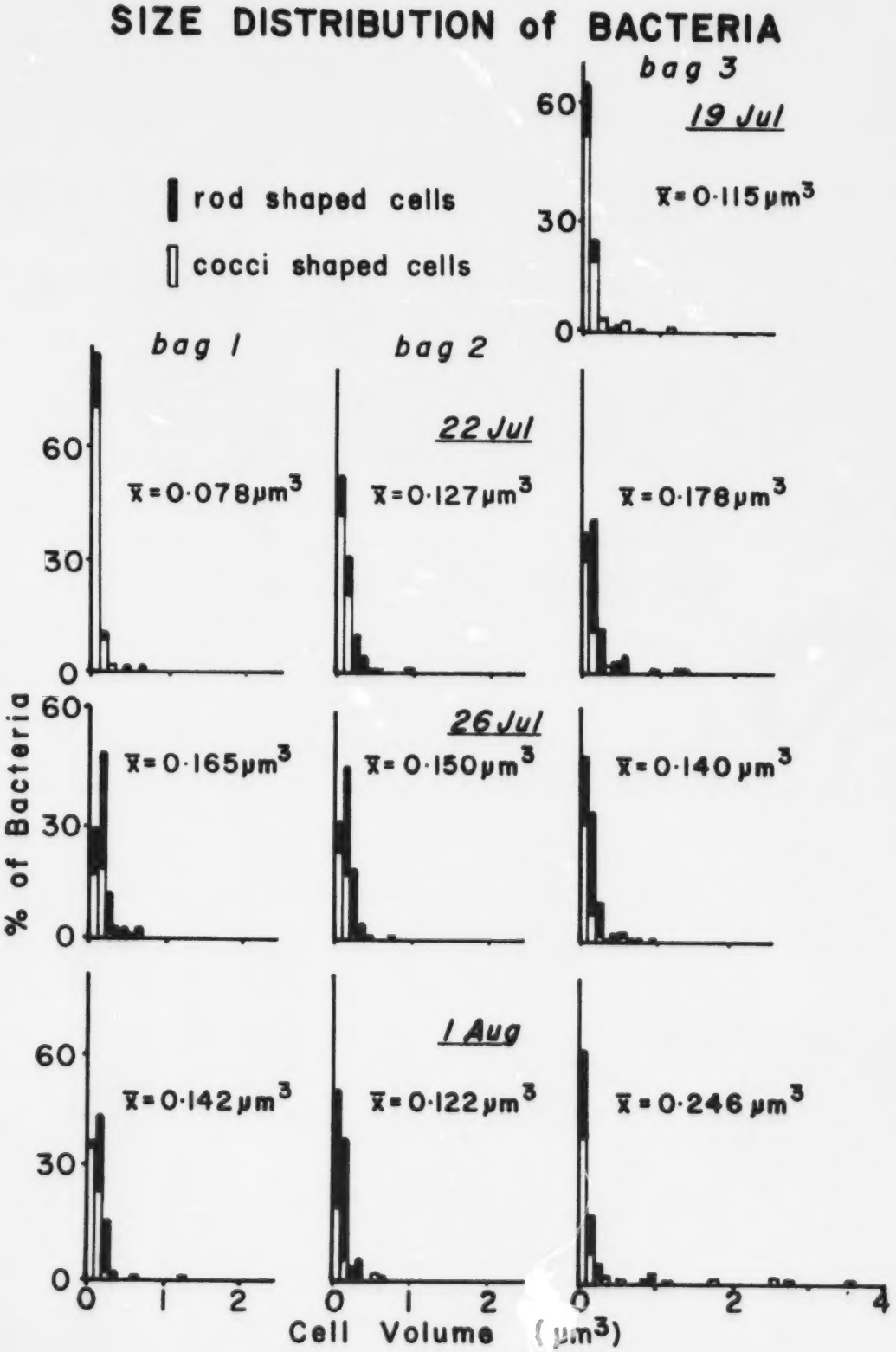

SIZE DISTRIBUTION of BACTERIA
bag 3
19 Jul
rod shaped cells
cocci shaped cells
x̄ = 0·115 µm³
bag 1
bag 2
22 Jul
x̄ = 0·078 µm³
x̄ = 0·127 µm³
x̄ = 0·178 µm³
26 Jul
x̄ = 0·165 µm³
x̄ = 0·150 µm³
x̄ = 0·140 µm³
1 Aug
x̄ = 0·142 µm³
x̄ = 0·122 µm³
x̄ = 0·246 µm³
% of Bacteria
Cell Volume (µm³)

TABLE 15 Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 1	Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
	DY:	18	20	22	24	26	29	01	04
TAXA									
Bacillariophyceae									
CENTRALES									
Chaetoceros affinis				200	103	31			
C. concavicornis		3		17	154	14			
C. convolutus		3			43				
C. constrictus				450	115	28			
C. debilis			450	4083	1235	1353	1		1
C. decipiens				33	8				
C. didymus			20	25					
C. gracilis				33	9	8			
C. laciniosus				183	137	83			
C. similis				42					
C. socialis				50	4	69			
Chaetoceros spp.		17	186	166	274	133			
Coscinodiscus spp.				8	30	8	1		
Ditylum brightwellii			4			6			
Eucampia zoodiacus				17		11			
Hemiaulus sp.					13				
Rhizosolenia delicatula				33	26	6			
R. fragilissima				25		17			
R. stolterfothii					4				
Rhizosolenia spp.					34	36	1		
Skeletonema costatum		6	30	983	667	189			
Thalassiosira spp.[A]		3	24	58	43	75	1		
Unidentified centrics			4	25	4				
TOTAL Centric Diatoms		32	718	6431	2903	2067	4	0	1

TABLE 15 (cont.) Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 1 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	01	04
TAXA								
PENNALES								
Asterionella glacialis			42	124	111	1		
Cylindrotheca closterium	6	28	58	81	14	4	44	106
Navicula spp.		8		56	14			1
Nitzschia delicatissima	3	36	208	132	89	2		
N. pungens		24	583[B]	124	128			
Nitzschia spp.		14	192	128	42			1
Thalassionema nitzschoides			233	51	36			
Amphiprora sp.								
Unidentified Pennates		20		9				
TOTAL Pennate Diatoms	9	130	1316	705	434	7	44	108
Dinophyceae	18	36	83	17	22	1		
Cryptophyceae	65	174	167	4				
Chrysophyceae		6						
Prasinophyseae	10							
Haptophyceae	2	6	133				1	
Microflagellates, 1-5µm	544	578	2817	3338	1548	981	538	306
5-10µm	25	56	233	213	336	34	31	69
10-20µm	6	8	17	125	68	25	13	13
TOTAL Microflagellates	575	642	3067	3676	1952	1040	582	388
TOTAL PHYTOPLANKTON	711	1712	11197	7305	4475	1052	627	497
Zooflagellates	161	?	1000	125	116	144	113	175
Ciliates	33	33	76	13	19	30	26	31

A - includes Thalassoisira aestivalis and T. gravida
B - epiphytic on Chaetoceros spp.

TABLE 15 (cont.) Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 2 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	01	04
TAXA								
Bacillariophyceae								
CENTRALES								
Chaetoceros affinis			188	51	42			
C. concavicornis			12	12	6			
C. convolutus				20	103			
C. constrictus			35	25	19			
C. debilis	33	870	4200	482	1789			
C. decipiens			104		32			
C. didymus				22	22			
C. gracilis		15	12	10	25			
C. laciniosus			47	63	225			
C. septentrionalis					3			
C. similis			35					
C. simples ?	8							
C. socialis		300	129	29	106			
Chaetoceros spp.	5	145	71	136	131			
Coscinodiscus spp.		5	6	6	28	1		
Ditylum brightwellii					3			
Eucampia zoodiacus		25		6	8			
Leptocylindus minimus	5							
Rhizosolenia delicatula			24	4	36			
R. fragilissima			41	1	58	1		
R. setigera	2		6					
R. stolterfothii		10	29					
Rhizosolenia spp.				9	47			
Skeletonema costatum	10	90	382	110	106			
Thalassiosira spp.A		25	59	9	22			
Unidentified centrics		45	47					
TOTAL Centric Diatoms	63	1530	5427	995	2801	3	0	0

TABLE 15 (cont.) Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 2 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	01	04
TAXA								
PENNALES								
Asterionella glacialis		90	141	32	81			
Cylindrotheca closterium	13	155	135	38	47	11	20	136
Navicula spp.	8	110[B]	18	48	106		1	1
Nitzschia delicatissima		95	353	392	331			
N. pungens	8	155	699	114	200	1		
Nitzschia spp.		15	47	23	47	3	1	
Thalassionema nitzschoides		10	88					
Amphiprora sp.								
TOTAL Pennate Diatoms	34	630	1481	647	812	15	22	137
Dinophyceae	30	130	101	?	31	0	0	0
Cryptophyceae	149	205	100					
Chrysophyceae	8	100	94					
Prasinophyseae		10	12					
Haptophyceae		60	53					
Euglenophyceae		5						
Other		10			6		1	
Microflagellates, 1-5µm	1238	2200	3371	1400	1382	1567	1250	469
5-10µm	132	300	145	273	482	58	156	56
10-20µm	2	15	16	107	273	38	56	25
TOTAL Microflagellates	1372	2515	3532	1780	2137	1663	1462	550
TOTAL PHYTOPLANKTON	1651	5195	10800	3422	5787	1681	1485	687
Zooflagellates	?	?	1096	133	1109	300	206	106
Choanoflagellates	5	5	48					
Ciliates	38	50	96	4	17	37	28	45

A - includes Thalassoisira aestivalis and T. gravida

B - epiphytic on Chaetoceros spp.

TABLE 15 (cont.) Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 3 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	01	04
TAXA								
Bacillariophyceae								
CENTRALES								
Chaetoceros affinis				28	9	12	5	
C. concavicornis	3		3	6	11			
C. convolutus				8	6			
C. constrictus			27	10	15	5		
C. debilis	8	198	159	180	196	103	41	
C. didymus				6			20	
C. gracilis		6		2	1	2		
C. laciniosus			4	13	24	2		
C. simplex		21						
C. socialis		543			5	1		
Chaetoceros spp.	19	21	15	27	24	13	9	
Coscinodiscus spp.							2	6
Ditylum brightwellii								
Eucampia zoodiacus							5	
Rhizosolenia delicatula	2		4	1	5	3	16	6
R. fragilissima				3	6	9	14	11
R. stolterfothii								
Skeletonema costatum	13	69	11		20			28
Rhizosolenia spp.		6	6	2	3	2		8
Thalassiosira spp.A			7	3	8			
Unidentified centrics		21		4				
TOTAL Centric Diatoms	45	885	264	274	336	145	107	59

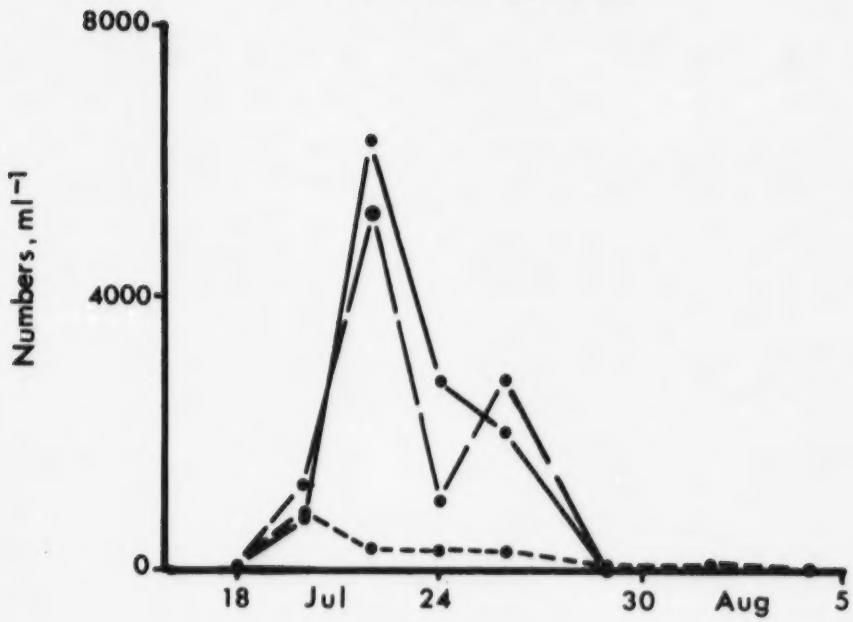
TABLE 15 (cont.) Phytoplankton Species and Protozoa Cells mL^{-1}

Bag # 3 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG
DY:	18	20	22	24	26	29	01	04
TAXA								
PENNALES								
Asterionella glacialis				2	9			
Cylindrotheca closterium	8	72	32	19	78	215	177	72
Navicula spp.	3	21	1	3	7	5	9	14
Nitzschia delicatissima	24	63	74	84	143	93	575	594
N. pungens		54	67	9	14	16	7	11
Nitzschia spp.	3	45[B]	1	23	29	64	64	14
Thalassionema nitzschoides			7	16	11		27	33
Amphiprora sp.						32	41	
Unidentified Pennates	6		5	3	19	43		
TOTAL Pennate Diatoms	38	261	182	161	291	444	943	738
Dinophyceae	40	48	4	1	53	72	259	247
Cryptophyceae	346	111		25				
Chrysophyceae	6	9						
Prasinophyseae	8							
Other	10	15	4		1		9	
Microflagellates, 1-5µm	359	951	4405	3025	8867	3238	12900	2757
5-10µm	62	105	310	329	1733	763	1133	529
10-20µm	5	0	24	152	400	350	633	214
TOTAL Microflagellates	426	1056	4739	3506	10000	4351	14666	3500
TOTAL PHYTOPLANKTON	919	2385	5191	3967	10681	5012	15984	4544
Zooflagellates		618	3048	152	833	613	1433	1343
Choanoflagellates	6	21						
Ciliates	25			2	2	3	30	31

A - includes Thalassoisira aestivalis and T. gravida
B - epiphytic on Chaetoceros spp.

PHYTOPLANKTON

CENTRIC DIATOMS



MICROFLAGELLATES

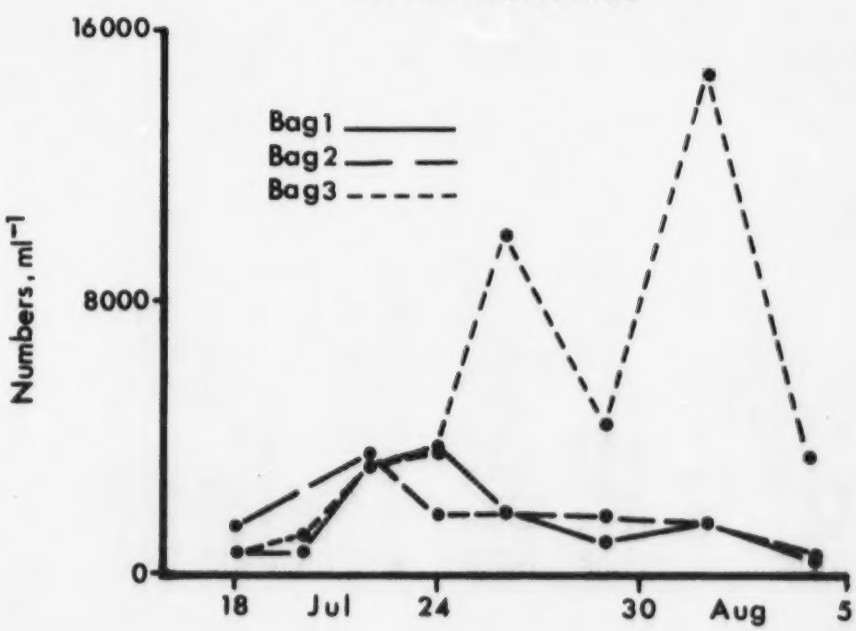


TABLE 16

Zooplankton Species number/sample*

Bag # 1

Species list \ Date, MO: / DY:	JUL 18	JUL 20	JUL 22	JUL 24	JUL 26	JUL 29	AUG 1	AUG 4	AUG 10
Oithona similis	120	108	512	256	528	288	144	0	2
Paracalanus parvus	88	168	240	48	16	2256	4064	3808	3482
Unidentified copepodites and nauplii	28	64	224	144	128	320	32	0	4
TOTAL Herbivorous copepods	236	340	976	448	672	2864	4240	3808	3488
Corycaeus sp.	26	20					48	80	430
Centropages abdominalis					16	16	224	56	2
TOTAL Carnivorous copepods	26	20	0	0	16	16	272	136	432
Oikopleura dioica	60	976	2704	3536	5120	800	592	296	724
Fritillaria borealis	36	756	2080	352	464	1280	1808	48	0
TOTAL Appendicularians	96	1732	4784	3888	5584	2080	2400	344	724
Meroplanktonic larvae	60	148	160	112	80	496	528	360	50
Pleurobrachia sp.					16	present	32	104	94
Beroe sp.								8	
Medusae									68
Siphonophores								24	16
Sagitta sp.							16		
Cladocera (Podon sp.)						48	288	168	
Gastropoda (Limacina helicina)									12
Ostracoda (Cypridina sp.)									
Protozoa (Noctiluca sp.)									460

* Volume sampled appr. 0.40 m^3
- 20 cm net, 200 um mesh, towed from 13 to 0 m.

TABLE 16 Zooplankton Species number/sample*

Bag # 2 Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
Species list DY:	18	20	22	24	26	29	1	4	10
Oithona similis	126	176	208	144	384	176	224	96	16
Paracalanus parvus	34	120	144	64	176	3216	5792	3480	4842
Unidentified copepodites and nauplii	12	32	80	80	16	192	80	24	2
TOTAL Herbivorous copepods	172	328	432	288	576	3584	6096	3600	4860
Corycaeus sp.	24						32	56	70
Centropages abdominalis					16	32	144	52	14
TOTAL Carnivorous copepods					16	32	176	108	84
Oikopleura dioica	52	796	2640	4544	6400	1888	1136	992	166
Fritillaria borealis	74	548	16		32		64	8	
TOTAL Appendicularians	126	1344	2656	4544	6432	1888	1200	1000	166
Meroplanktonic larvae	84	160	240	80	16	608	528	172	40
Pleurobrachia sp.						96	32	4	14
Beroe sp.								12	
Medusae								8	6
Siphonophores									
Sagitta sp.	2								
Cladocera (Podon sp.)							112	96	4
Gastropoda (Limacina helicina)									8
Ostracoda (Cypridina sp.)									16
Protozoa (Noctiluca sp.)									38

* Volume sampled appr. 0.40 m^3
- 20 cm net, 200 um mesh, towed from 13 to 0 m.

TABLE 16

Zooplankton Species number/sample*

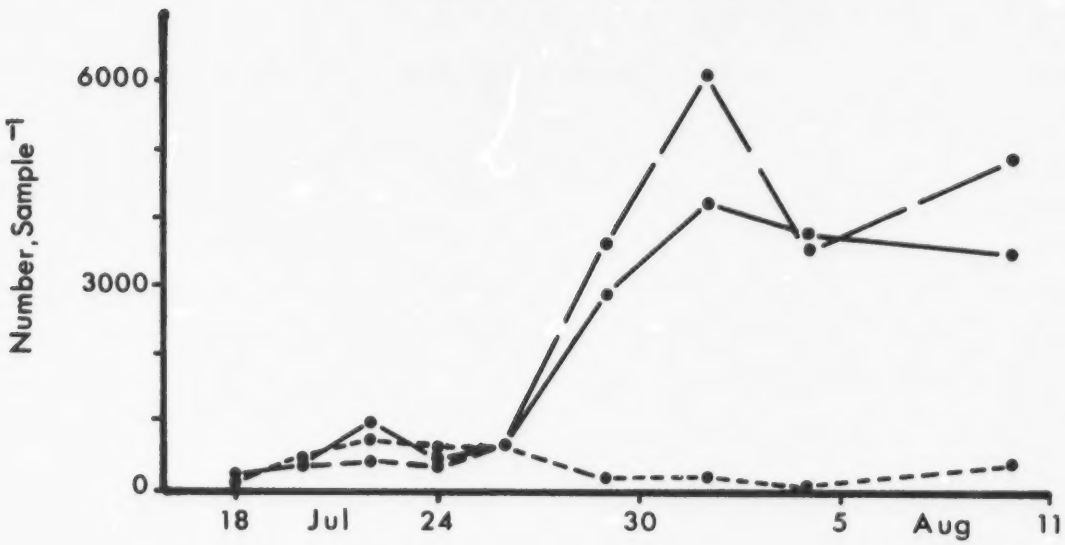
Bag # 3

Species list	Date, MO:	JUL	JUL	JUL	JUL	JUL	JUL	AUG	AUG	AUG
	DY:	18	20	22	24	26	29	1	4	10
Oithona similis		10	264	612	552	484	84	60	12	8
Paracalanus parvus		18	126	52	48	60	88	126	74	360
Unidentified copepodites and nauplii		28	72	80	32	56	16	4	0	1
TOTAL Herbivorous copepods		56	464	744	632	600	188	190	86	369
Corycaeus sp.		4		4	4	8				
Centropages abdominalis										
TOTAL Carnivorous copepods		4		4	4	8				
Oikopleura dioica		6	104			4	34	10	4	
Fritillaria borealis		2	208						10	1451
TOTAL Appendicularians		8	312			4	34	10	14	1451
Meroplanktonic larvae		12	68	12	8	8	4	12		3
Pleurobrachia sp.										
Beroe sp.										
Medusae			4							
Siphonophores										
Sagitta sp.						4				
Cladocera (Podon sp.)									2	
Gastropoda (Limacina helicina)										
Ostracoda (Cypridina sp.)										
Protozoa (Noctiluca sp.)										

* Volume sampled appr. 0.40 m^3
- 20 cm net, 200 um mesh, towed from 13 to 0 m.

ZOOPLANKTON

HERBIVOROUS COPEPODS



MEDUSAE & CTENOPHORES

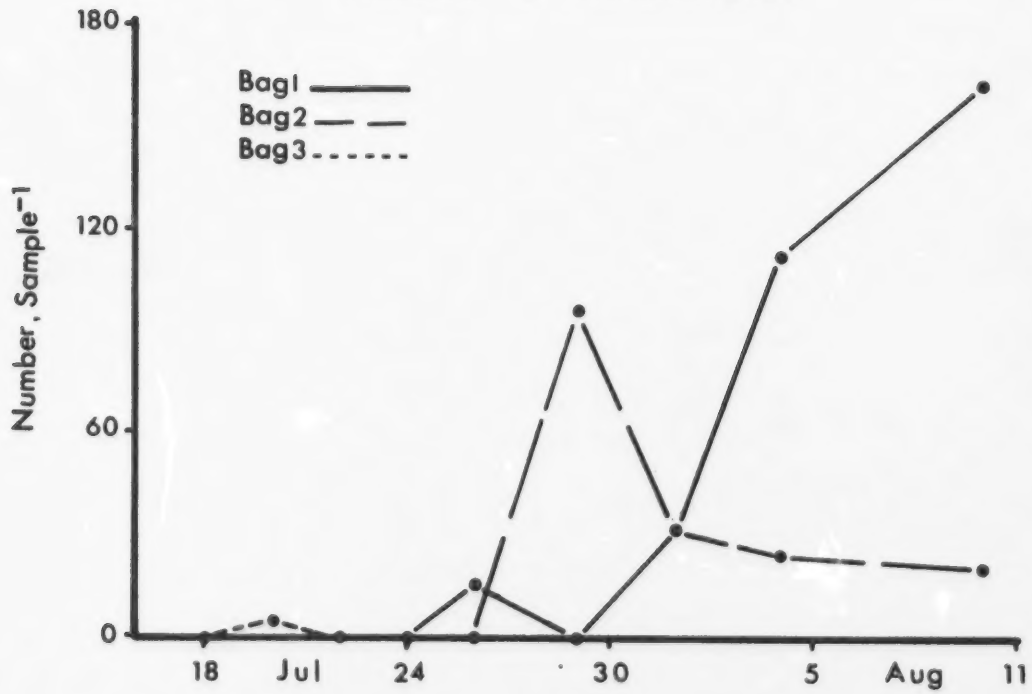


TABLE 17 Relative Heterotrophic Uptake mg Glucose m^{-3} h^{-1}

Date MO: / DY:	JUL 18	JUL 20	JUL 22	JUL 24	JUL 26	JUL 29	AUG 1	AUG 4
Bag # 1								
0-5 m	0.58	1.04	1.64	1.40	1.57	1.17	0.36	0.35
5-10 m	0.26	0.68	0.44	1.39	2.57	0.81	0.54	0.28
10-13 m	0.36	0.41	0.35	1.28	2.05	1.87	1.50	1.23
Bag # 2								
0-5 m	0.86	2.00	2.66	2.50	2.89	1.71	0.63	0.31
5-10 m	0.44	0.80	1.09	2.66	4.57	1.08	1.67	0.20
10-13 m	0.42	0.66	0.71	1.93	5.76	2.08	2.51	0.54
Bag # 3								
0-5 m	1.24	1.41	3.41	5.04	1.62	2.87	0.44	0.71
5-10 m	0.54	0.93	1.98	4.96	1.58	1.93	0.63	0.48
10-13 m	0.42	1.14	1.22	1.65	1.24	1.65	0.31	0.32

No blank correction at t=0 were applied to these data.

TABLE 18 Sinking Rates of Particles $m\ d^{-1}$

Date	Bag # 1	Bag # 2	Bag # 3
18 Jul	0.39	0.45	0.37
20 Jul	0.12	0.14	0.013
22 Jul	8.8	5.9	0.37
24 Jul	8.0	8.1	0.57
26 Jul	3.4	5.7	2.6
29 Jul	0.9	2.6	1.0
1 Aug	4.5	6.6	7.3
4 Aug	0.8	1.4	5.1

Measurements on 0-5 m samples using total particle count, 3-80 μm.

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 18, 1983

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	11420	6983	7415	13326	6289	8193	13320	6913	11563
4.0	7295	3660	3064	8530	3864	3816	8005	3762	4239
5.0	3043	1202	1286	3541	1297	1455	3242	1489	1712
6.4	1459	641	678	2029	774	715	1534	883	803
8.0	674	281	271	1109	353	220	209	428	281
10.1	193	166	86	409	166	78	251	172	111
12.7	134	43	41	210	106	34	144	111	74
16	96	25	24	105	41	13	110	42	21
20.2	48	18	19	34	23	9	65	22	8
25.4	18	11	30	80	33	8	22	11	10
32	11	12	14	6	15	10	12	7	5
40.4	8	14	13	1	19	6	7	3	3
50.8	2	13	10	2	21	1	0	3	2
64	2	3	5	0	9	6	0	4	1
>80.6	2	3	6	0	11	2	0	0	0
Total	24384	13021	12888	29322	12864	14572	27533	13874	18843

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 20

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	18280	9053	6632	18230	7974	8274	29472	12009	7268
4.0	11252	4076	3493	13712	4770	3176	31484	5825	3370
5.0	5378	1805	1544	6660	1974	1518	22770	2428	1582
6.4	3842	1101	879	4156	1316	916	10551	1307	883
8.0	2851	521	384	3102	715	451	4324	640	388
10.1	1073	222	208	1185	270	176	1751	284	148
12.7	513	142	101	532	128	104	566	134	80
16	250	85	55	246	69	36	286	70	20
20.2	188	52	20	185	37	22	111	29	14
25.4	131	31	15	139	23	18	72	20	14
32	109	34	15	82	24	10	45	14	6
40.4	54	14	6	52	13	10	25	6	10
50.8	30	9	2	18	6	9	11	8	4
64	19	4	3	-	2	1	1	4	2
>80.6	6	1	2	3	3	2	0	0	1
Total	43985	17150	13362	48340	17331	14721	101479	22778	13803

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 22

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	20928	15044	10152	17570	15716	4631	35045	34285	19847
4.0	9005	6994	4585	7687	6951	2216	30951	20358	9150
5.0	4733	3624	2443	4193	3656	1356	19184	9816	4463
6.4	4261	2593	1699	3856	2996	421	8082	3884	1711
8.0	2785	1665	659	2755	2189	178	2722	1498	802
10.1	1231	695	334	1379	986	70	1119	572	305
12.7	686	374	148	728	520	33	415	258	122
16	716	365	112	696	433	28	212	124	86
20.2	786	371	101	708	366	25	80	62	49
25.4	606	342	88	550	272	20	64	32	38
32	405	274	72	396	228	12	39	35	24
40.4	140	61	32	120	76	5	11	10	10
50.8	32	33	18	49	27	5	6	8	8
64	16	13	9	21	11	3	1	3	2
>80.6	14	4	2	8	4	2	1	2	1
Total	46354	32452	20462	40718	34440	9009	97839	70981	36618

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 24

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	15271	33005	20716	17324	20023	20269	38396	35953	28976
4.0	5869	15343	10156	7132	8314	10010	30206	23323	13200
5.0	3042	5664	5380	3376	3804	6115	17295	12155	5906
6.4	1809	2399	3275	2093	2038	4080	7533	5458	2612
8.0	1064	1261	1994	1376	1292	2569	3003	2658	1390
10.1	560	801	1069	744	762	1464	1202	1154	581
12.7	422	536	771	525	549	1131	553	414	216
16	485	586	906	605	622	1299	278	258	136
20.2	613	898	1077	752	762	1236	132	164	83
25.4	331	686	954	464	516	1002	81	109	65
32	153	482	854	243	353	803	44	76	45
40.4	42	159	283	75	104	236	8	18	9
50.8	11	30	65	17	32	100	1	7	8
64	8	13	46	13	4	43	0	3	0
>80.6	2	7	10	0	6	8	0	1	1
Total	29680	61873	47562	34744	39181	50381	98732	81753	53240

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 26

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	11389	10845	15581	9707	15416	17359	26396	27000	21722
4.0	3878	4539	5961	3890	6529	7224	17563	18574	12410
5.0	1731	2024	2696	1849	2921	3566	10451	10302	6915
6.4	1215	1321	1729	1411	1715	2456	7658	7171	5043
8.0	751	872	1161	879	1109	1682	4976	4701	2938
10.1	534	646	847	671	826	1309	2392	2321	1399
12.7	451	640	853	613	778	1172	880	875	566
16	408	663	921	645	722	1179	415	372	284
20.2	431	634	909	621	639	990	207	208	168
25.4	220	501	771	374	426	813	133	125	95
32	136	420	703	219	309	566	54	75	58
40.4	57	110	232	63	89	153	6	16	21
50.8	20	25	59	36	53	47	1	11	8
64	12	9	15	8	24	23	1	4	1
>80.6	12	3	10	14	8	11	1	3	1
Total	21250	23459	32448	21003	31564	38556	71141	71765	51628

TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date July 29

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	6134	6934	8448	6335	6556	6640	18444	17172	15208
4.0	5851	7321	7524	3686	4062	3829	14734	10394	7594
5.0	1535	1980	2722	960	1093	1038	9036	5214	4242
6.4	191	235	351	218	171	245	5761	3459	3010
8.0	90	89	125	83	73	136	2261	1640	1571
10.1	94	91	100	68	62	115	776	690	825
12.7	70	48	76	76	44	93	479	374	512
16	38	30	46	61	28	80	212	207	249
20.2	27	26	29	42	22	45	72	124	141
25.4	23	24	34	34	28	44	41	56	66
32	15	5	26	25	12	19	11	21	38
40.4	15	19	20	9	12	15	1	14	13
50.8	4	11	9	6	11	11	0	9	4
64	4	9	7	3	5	8	0	6	1
>80.6	4	0	3	3	2	1	0	0	1
Total	14095	16822	19520	11612	12184	12318	51834	39390	33473

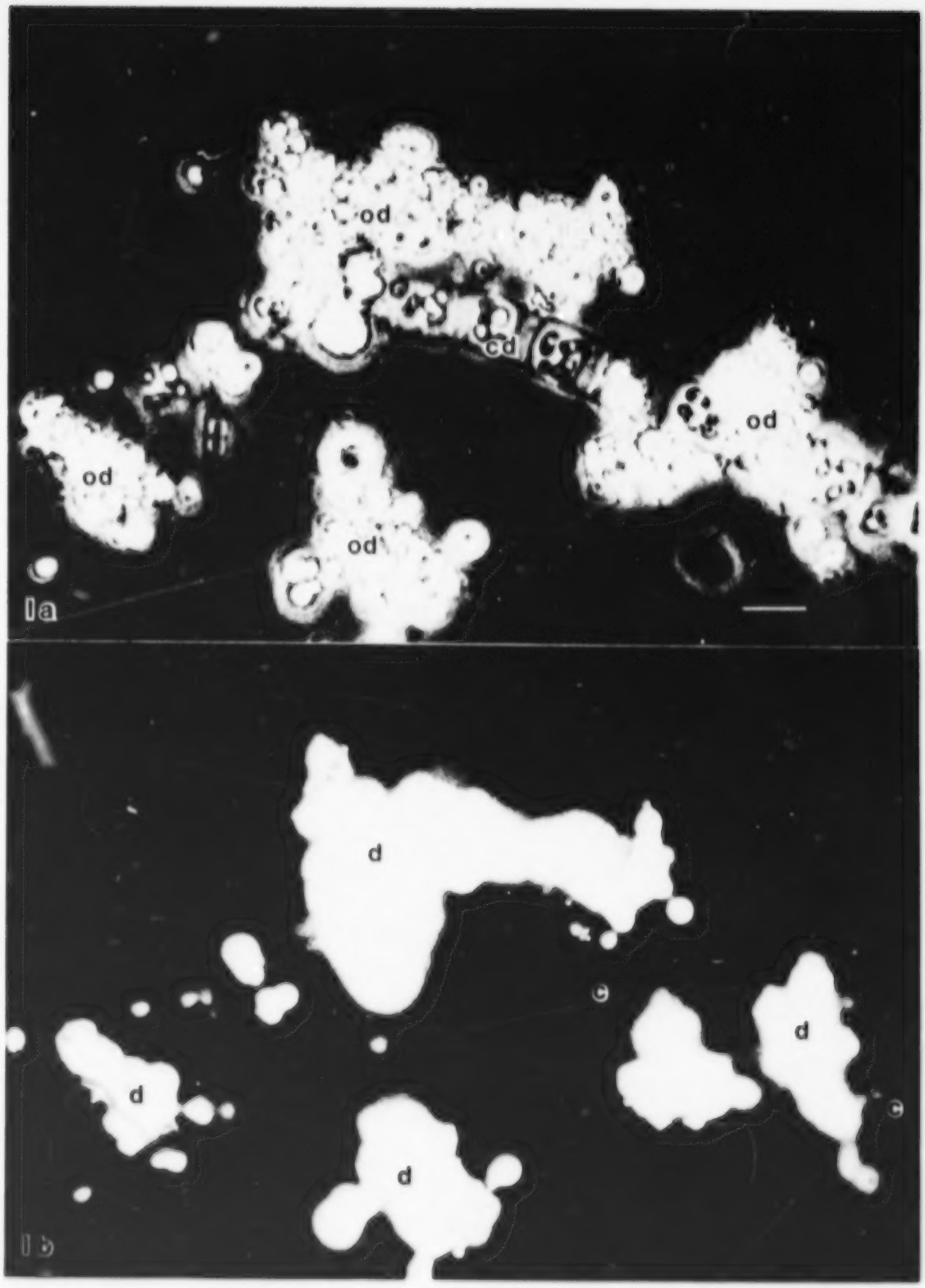
TABLE 19 Size Distribution of Particles number of particles/2 mL water

Date August 1

Particle Diameter (μm)	Bag # 1			Bag # 2			Bag # 3		
	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m	2.5m	7.5m	11.5m
3.2	4381	3566	4321	4769	5160	9102	21874	24018	19051
4.0	1626	1878	1931	2117	1594	1818	17403	19758	13333
5.0	611	498	392	700	454	439	11455	11373	7015
6.4	211	121	128	222	118	138	8196	7720	4916
8.0	113	95	59	68	41	86	3314	3996	2420
10.1	63	78	43	40	40	56	1669	1601	1141
12.7	63	52	36	61	71	33	1224	918	595
16	46	26	25	45	56	26	301	389	346
20.2	26	19	21	51	22	15	66	153	189
25.4	45	36	28	43	33	18	45	107	64
32	10	18	16	20	28	5	30	40	30
40.4	7	20	13	24	16	9	10	12	14
50.8	10	12	1	15	13	6	6	13	6
64	4	5	5	15	9	6	0	7	3
>80.6	4	0	2	5	5	0	0	2	0
Total	7233	6423	7027	8194	7660	11755	65602	70111	49123

Plate 1a. Phase contrast microscopy: centric diatoms (cd); oil droplets (od). Bar = 10 um.

1b. Epifluorescence microscopy of the identical sample above. Chloroplast auto-fluorescence (c); fluorescent oil droplet (d). Bar = 10 um.


od
od
od
od
1a
d
d
d
d
1b

SCANNING ELECTRON MICROGRAPHS

Plate A. Centric and pennate diatoms from a 3 m sample in bag 1 on day 5. Magnification: 750X.

A

Plate B. Centric and pennate diatoms from a 3 m sample in bag 2 on day 5. Magnification: 750X.

B

Plate C. Centric diatom chain from a 3 m sample in bag 3 on day 5. Magnification: 750X.